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APPLICATION OF LIFE CYCLE COST CONCEPT IN WEAPON SYSTEMS ACQUISITION FOR THE KOREA MILITARY

by

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and

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June 1986

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Application of Life Cycle Cost Concept in Weapon Systems Acquisition for the KOREA Military

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June 1986

ABSTRACT

This thesis deals with the Life Cycle Cost (LCC) concept and life cycle costing techniques. It also presents the LCC application methodology in new weapon systems acquisition for the Republic of Korea(R.O.K.) military.

Historically, the acquisition of a weapon system in the Republic of Korea has been made on the basis of system effectiveness and initial acquisition cost, with little or no consideration being given to Operating and Support(O&S) costs that will be incurred after the system is deployed in the field. The Korea has concentrated on self-production since 1976. Also, Korea still acquires most of its sophisticated weapon systems from foreign countries. Under this situation, broad understanding of LCC concept and techniques are needed.

This thesis introduces the LCC concept, Life cycle costing techniques and the methodology for Life Cycle Cost analysis. Then, the aircraft cost-estimating models for application are reviewed. It proceeds with applying the LCC for the aircraft acquisition program. By using the cost-estimating model, two alternative aircraft (F-14, F-18) and an existing aircraft(F-4) are compared, then the preferred alternative for the R.O.K. is selected on the basis of LCC results. It is shown that the F-18 is the preferred alternative aircraft among the two alternatives.

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I. INTRODUCTION

A. BACKGROUND

In recent years the military sevices have increasingly emphasized Life Cycle Cost (LCC) of new weapon systems in an effort to reduce rising acquisition costs and operating and support costs (O&S).

Traditionally, military procurements have emphasized unit cost as the major determining factor in weapon system acquisition. As the results of emphasis on unit cost, their O$S costs after the systems are placed into operation are rapidly increasing. The cost of operating and supporting over their useful life is generally greater than, and often several times greater than, the initial acquisition price. Therefore, including these future costs as part of the decision criteria just makes good sense. Reduction in O&S costs can be brought about primarily through increased consideration of these costs in various design and support decisions. Since the objective is to reduce LCC, i.e., total cost, equal emphasis must be given to all costs, research and development, production, and O&S cost.

Historically, the acquisition of weapon systems in the Republic of Korea (R.O.K.) has been made on the basis of system effectiveness and initial acquisition cost, with little or no consideration being given to O&S costs that will be incurred after the systems are deployed in the field.

ROK is confronted with the dilemma of budgeting constraints, a constant and formidable threat from North Korea, and a desire for sophisticated weaponry. As a developing nation, ROK is faced with difficult decisions trading off military strength and economic growth.

In every year, about six percent of the GNP which accounted for one-third of the national budget, was spent on defense. One-third of the defense expenditure, also, was spent on equipment maintenance. Korea has concentrated on self-production as one of Force Improvement Plans (FIP) since 1976. However, the ROK still acquires most of its sophisticated weapon systems from foreign countries. This situation puts increasing pressure to reduce defense spending and has encouraged new approaches to managing weapon systems acquisition and O&S costs.

During the acquisition stage, if no consideration is given to O&S cost, the R.O.K. will be confronted with unbugeted future O&S costs incurred by the new systems. If this pattern is allowed to continue, the bulk of the annual defense budget will be allocated to support existing systems, thereby reducing or perhaps delaying for a long time, future acquisition programs.

B. OBJECTIVES

This research introduces the LCC concept within the Republic of Korea military and presents the LCC application methodology through a hypothetical aircraft acquisition program.

Korea has concentrated on self-production as one of the Force Improvement Plans (FIP) since 1976. However, Korea still acquires most of its sophisticated weapon systems from other countries where such systems already have been developed, tested, produced and deployed. For this reason, the methodology developed here is devoted to the life cycle cost approach in terms of logistic as a criterion for selecting the preferred alternative when the weapon systems are acquired from a foreign country.

Korea currently needs a broad understanding of LCC concept. Therefore, we have avoided indulgence into detailed methodology as a acquisition technique and have

focused on theoretical study and life cycle cost approach as one method of acquisition techniques.

C. THESIS ORGANIZATION

Chapter II deals with the weapon systems acquisition strategy in R.O.K. It also presents a brief summary about Korea's weapon systems production and purchase.

Chapter III describes the LCC concept, history, uses of LCC information and weapon system life cycle stages and costs.

Chapter IV describes the key factors affecting LCC. Reliability and maintainabilty as a major factor affecting LCC are emphasized.

Chapter V provides a basic knowledge of the acquisition process and the ways life cycle costing may be used throughout the acquisition process of a weapon system.

Chapter VI describes methodology for LCC analysis.

Chapter VII describes techniques and concepts for cost estimating. This chapter provides the basic knowledge of three cost estimating techniques: learning curve, discounting, and inflation.

Chapter VIII reviews the aircraft cost estimating models that are used in the application for the Korea's aircraft acquisition program. This Chapter includes the Research, Development, Test and Evaluation(RDT&E) and Flyaway cost-estimating model and the Naval Aircraft O&S costs estimating model.

Chapter IX deals with the application of LCC for the aircraft acquisition in R.O.K. Two alternative aircraft (F-14,F-18) and one existing aircraft's(F-4) LCCs are compared, then the preferred alternative for the R.O.K. is selected on the basis of LCC results. Analytical results are focused on LCC in terms of logistics support.

Finally, Chapter X presents the conclusions and recommendations.

II. WEAPON SYSTEMS ACQUISITION STRATEGY IN REPUBLIC OF KOREA(R.O.K.)

Acqusition is defined as the means of acquiring by contract, with appropriate funds, of supplies (including construction) by and for the use of the Government through purchase, lease, or barter, whether the supplies or services are already in existence or must be created, developed, demonstrated, and evaluated.

Acqusition begins at the point when agency needs are established and includes solicitation and selection of sources, award of contracts, contract financing, contract performance, contract administration, and those technical and management functions directly related to the process of fullfilling agency needs by contract. [Ref. 1: p. 19]

Small countries are not normally capable of satisfying all their military needs through internal manufacturing due to a lack of domestic resources. The required combination of large amounts of capital, raw materials, advanced technology, and skilled manpower needed for the establishment and operation of defense-oriented industries can rarely be found in small countries. [Ref. 2: p. 8]

The acquisition strategy of a weapon system can be divided as follows:

1. Self-production.
2. Co-production.
3. Direct purcase.
4. Cooperative production.
5. Military aid.
6. Mixed type.

In the concrete, self-production comprises pure R&D and production, copy production of the existing system, and modification production. Co-production includes technology

import, license, royalty, and hardware import type. Direct purchase can be classified either by purchase route or condition. Cooperative production involves joint production, joint venture, and multi-national industry. Military aid is divided into grant-aid and foreign military sale (FMS).

In developing countries whose industry and economic power are behind, self-production may not be the best alternative. [Ref. 3: p. 124]

What is the best strategy? It depends on the situation. Under the enemy's threat and time constraint for self-production, direct purchase may the best way. Also, co-production may be a better strategy because of limited technology to produce high-level systems. Sometimes, joint production was undertaken by allied nations to improve economical benefits and strengthen the allied relationships.

Self-production of a weapons system must be the ultimate goal for the ROK self defense endeavor. ROK has concentrated on self-production since 1976, even if it has some disadvantages such as more R&D and production cost, more time, and higher failure probability during R&D. But, it has advantages such as techno-economic effects to the other industries, enhancement of people's morale, and inspiration of self-defense spirit.

This chapter will briefly review the weapons system acquisition strategy in the R.O.K.

A. WEAPON SYSTEM PRODUCTION

The ROK is currently developing an indigenous weapons production industry as part of the Force Improvement Program. Professor Young-Sun Ha of the Seoul National University breaks the development of the ROK defense industry into four distinct phases. This development is establishing Korean's position as a major arms producer and exporter among developing nations. [Ref. 4: p. 225]

The first phase (1968-1971) began with President Park's decision to build munitions factories in response to a North Korean attack on the presidential mansion. [Ref. 4: p. 225] This proved to be only the beginning of the ROK weapons industry. After President Nixon announced in 1969 his plan to reduce the number of U.S. troops stationed in Korea, President Park felt a strong need to develop the range of the defense industries.

During the second phase (1972-1976), ROK expenditures for the research and development of weapon systems began a gradual steady growth as is depicted in Table I. [Ref. 4: p. 226] and [Ref. 9: p. 5]

TABLE I

ROK DEFENSE EXPENDITURES BY APPROPRIATIONS CATEGORY

(Current Million Won)

Year	Personnel	Maintenance	R&D	Investment	Total
1961	12,743	2,948	---	896	16,587
1962	16,774	2,867	---	831	20,476
1963	16,792	2,762	---	924	20,478
1964	20,795	3,191	---	940	24,926
1965	24,643	3,923	---	1,306	29,874
1966	31,953	7,001	---	1,588	40,542
1967	35,559	10,377	---	3,569	49,504
1968	44,914	13,302	---	6,472	64,708
1969	55,780	17,457	---	11,146	84,383
1970	69,073	22,968	---	10,295	102,336
1971	81,825	38,217	341	14,365	134,748
1972	96,987	55,500	2,054	19,097	173,638
1973	108,131	60,391	2,137	12,971	183,630
1974	144,107	123,153	8,234	21,348	296,842
1975	208,720	141,169	12,726	79,854	442,439
1976	298,920	170,975	36,035	197,818	703,748
1977	393,301	234,943	36,224	285,165	949,624
1978	483,557	336,539	30,878	483,379	1,289,353
1979	592,828	451,776	45,389	436,868	1,525,861
1980	792,401	751,607	70,751	642,624	2,257,383
1981	n. a.	n. a.	n. a.	n. a.	2,689,919
1982	n. a.	n. a.	n. a.	n. a.	3,179,944
1983	n. a.	n. a.	n. a.	n. a.	*3,189,034
1984	n. a.	n. a.	n. a.	n. a.	*3,386,217

* estimated totals

Initially, the Agency of Defense Development(ADD) chose ten basic systems for production such as hand grenades,

mines, and small radio sets [Ref. 4: p. 225]. The budding defense industry was aided by the enactment of the Provisional Law for the Promotion of Military supply which provided for economic assistance, guaranteed profits, and the elimination of military service commitments for workers in these industries. [Ref. 4: p. 227]

This phase also saw the implementation of the Force Improvement Program, which was intended to create a self-defense capability through ROK industries within four to five years' time [Ref. 4: p. 227]. President Park sought to have critical defense industries operating by 1979 and to "raise them to a world-class level early in the 1980s with the exception of highly sophisticated electronic equipment, high-technology fighter aircraft, and nuclear weapons." [Ref. 4: p. 227]

In 1977 President Carter announced that U.S. troops would be withdrawn from Korea within five years; this precipitated President Park's decision to increase the development of its weapon industry and marked the beginning of the third phase (1977-1981). The ROK, under the direction of the ADD, began developing and producing highly sophisticated weapon system like surface-to-surface missiles. It also began efforts to produce a sophisticated aircraft through a coassembly program of the Northrop F-5E/F fighter, though the U.S. government rejected a proposal to coassemble the F-16. [Ref. 4: p. 228]

In this third phase, the defense industries reached a production level at which many of Korea's weaponry needs were being met, and new markets were sought to allow production lines to continue operating. [Ref. 4: p. 229]

> However, as the United States continued to tightly control the export of military hardware through U.S. assistance to third countries, the operation rate of the Korean defense industry rapidly declined in this period. [Ref. 4: p. 229]

The fourth phase began in 1982 and is programmed to continue through 1986 under the second Force Improvement Program which was implemented despite President Reagan's decision to keep U.S. forces in Korea [Ref. 4: p. 229]. This Force Improvement Program is intended to upgrade the ROK forces through the indigenous industries and U.S. Foreign Military Sales. President Chun is now seeking the local development of high technology weapon systems [Ref. 4: p. 229]. The first coproduced F-5 was successfully tested in September 1982 and 20 percent of the aircraft's parts were ROK manufactured. By the time the F-5 coassembly is completed in 1986, the ROK's goal is to be manufacturing 75 percent of the aircraft's parts. [Ref. 4: p. 231]

Despite growing ROK self-sufficiency in arms production, the U.S. government continues to restrict the sale of Korean weapons, produced with U.S. technology, to Third World Nations. The U.S. is, however, seeking policies which will permit these sales without endangering U.S policy or degrading the U.S. industrial base [Ref. 4: p. 231]. The ROK will also shift its focus from weapons that copy the U.S. systems to the development of weapons that are better suited for Korean conditions, thus improving combat effectiveness and avoiding potential export controls [Ref. 4: p. 231]. It is certain that the Korean defense industry will continue to expand in the coming years and will locally produce a continually increasing amount of weapons.

B. WEAPON SYSTEMS PURCHASES

The ROK's FMS purchases are directed at fullfilling one or more of these intended goals: modernization of forces, self-sufficiency, the growth of advanced technology, and security. The goal of ROK force modernization has been very clearly demonstrated by the implementation of the Force Improvement Program (FIP). The FIP "emphasized increasing modern fighter aircraft and anti-tank capability ; improving

the tank force, air defense, and logistics..." [Ref. 5: p. 214]. Details of the FIP are classified ; however, it is known that the "ROK's Force Improvement Plans (FIP) have been used to upgrade the quality and capability of its armaments and to improve the managerial and technical competence of its military personnel." [Ref. 7: p. 93]

Self-sufficiency in weapons production, as previously discussed, is a major objective of the FIP. The second FIP emphasizes

> . . . the development of the indigenous arms industry in order to reduce this outflow of money from the country. Currently more than 2 percent of the ROK defense budget is spent in the U.S. [Ref. 8: p. III-2]

The ROK is attempting to locally produce all unsophisticated military items,

> where the technical expertise is not present or where production runs of expensive items would be too short to justify setting up production facilities, coproduction has been sought. [Ref. 8: p. III-2]

Coproduction efforts help to keep money in the ROK economy and enhance the Korean's effort to achieve their goal of self-sufficiency in weapons production.

The goal of obtaining advanced technology is related to the desire for self-sufficiency. The ROK recognizes that it will be unable to produce highly sophisticated weapon systems without an inflow of Western technology. The demand for sophisticated weaponry is growing, and ROK has joined those nations who are purchasing the most advanced weapons available. However, beyond simply purchasing these systems, and in order to educate the technical and production base, coproduction has become an important method of transferring technology and technical capability. The level of technology transfer "is an absolutely essential determinant for

dictating the rate and complexity of Korean technological advancement in the aircraft industry." [Ref. 6: p. 70] Further, "the more expensive the transfer of advanced technology the more valuable the spillover effect will be to R.O.K. industry." [Ref. 6: p. 171]

Clearly, obtaining advanced technology is crucial to the ROK if they are to develop the capability for producing sophisticated weaponry. This capability will allow them to achieve the goal of self-sufficiency as well as strengthening the ROK economy by reducing the monetary outflow from purchasing weapons abroad and by increasing the monetary inflow through arms sales to Third World Nations.

Finally, the arms that Korea purchases must fullfill a defense need. This is the fourth, and perhaps most important goal; that of national security. Clearly, weapons are procured in order to deter the threat facing the nation. It must, therefore, be recognized that insuring the national security is the primary motivation behind the ROK's purchases of weapon systems.

III. THE CONCEPT OF LIFE CYCLE COST

A. THE CONCEPT OF LIFE CYCLE COST

One of the most important weapon system acquisition concepts to emerge in recent years is that of life cycle cost (LCC). National leadership and Department of Defense(DoD) top management have recognized that the cost of acquiring and supporting weapon systems is far too high. In previous years, systems were (and still usually are) procured on the basis of best technical performance and lowest acquisition cost. The LCC concept, on the other hand, dictates that the Services define their minimum acceptable requirements and then procure the system which will meet those minimum requirements at the lowest cost for the entire life of the system. [Ref. 15: p. 1]

Air Force Regulation 800-11 defines a life cycle cost as follows :"The total cost of an item or system over its full life. It includes the cost of development, acquisition, ownership(operation,maintenance, support,etc.) and, where applicable, disposal." Acquisition cost includes the cost of research, development, test and evaluation (RDT&E), production or procurement of the end item; and the initial investments required to establish a product support capability (e.g. support equipment, initial spares, technical data, facilities, training etc). Ownership cost includes the cost of operation, maintenance,and follow-on logistics support system.

The terms "ownership cost" and "operating and support (O&S) cost" are synonymous. Thus, the four major cost categories included in the LCC estimate are research and development, production, operating and support, and disposal.

In the context of this paper, life cycle costs are to be understood as the total cost to the ROK Government for the acquisition and ownership of a particular system. Life cycle costing ,therefore, is the technique by which analytical study of a system's LCC is accomplished, taking into consideration the total costs of ownership(all operating and support costs, as well as the acquisition prices) for the useful life of the system. Also, it is an acquisition or procurement technique which considers operating, maintenance and other costs of ownership as well as acquisition price, in the award of contracts for hardware and related support.

The objective of using life cycle costing is to enable decision makers during the acquisition process to consider all costs of ownership as well as those development and acquisition costs which are closest on the fiscal horizon. By considering all costs throughout the system life cycle, the program manager has more visibility into the total economic advantages and disadvantages of various design and development options open to him. [Ref. 15: p. 2]

The use of LCC assumes that the decision concerning the acquisition of a weapon system is to be made by evaluating total LCC, and choosing the system from among those providing a given level of effectiveness and having the lowest LCC. The validity of this assumtion rests on a presentation of the acceptability of a temporal transfer of the budget between years, without regard to the probability of war, or so far in the future, that the decision can focus on peacetime costs only.

B. AN HISTORICAL PROFILE OF LCC

The concept of life cycle costing has been accepted for over 20 years as being applicable to the DoD acquisition process. Its basis is founded in DoD polices, directives, the Armed Services Procurement Act and the Defense Acquisition Regulation. The Armed Services Procurement Act

of 1947 states: "Award shall be made...to the responsible bidder whose bid...will be most advantageous to the United States, price and other factors considered." [Ref. 39: p. 1]

The supporting report of the Senate Committee on the Armed Services confirmed that "other factors" included consideration of "ultimate cost." Nevertheless, award of contracts on the basis of acquisition price alone continue to be the predominant practice by an overwhelming proportion [Ref. 5: p. 1]. Furthermore, the Armed Services Procurement Regulation (ASPR) states, "It is the policy of the Department to procure supplies from responsible sources at fair and reasonable prices calculated to result in the lowest ultimate overall cost to the Government." [Ref. 40: p. 1-1]

Defense Procurement Circular #115, dated 24 September 1973, added a section on life cycle costing to the ASPR(section 1-335).
This section states:

> Since the cost of operating and supporting the system or equipment for its useful life is substantial and,in many cases greater than the acquisition cost, it is essential that such costs be considered in development and acquisition decisions in order that proper consideration can be given to those systems or equipments that will result in the lowest life cycle cost to the government.

Although LCC consideration is mandated by this regulation, it should be noted that the LCC technique is seldom used to its full potential as a program management tool.

During the mid-1960's the rapidly increasing technical complexity of defense acqusitions led to steadily rising unit procurement costs. These increases in costs along with a general economic inflationary trend resulted in vigorous efforts to constrain the cost growth then associated with military systems acquisition.

The increased emphasis on cost during the 1960's led to techniques which included cost as a major system evaluation criterion. Prior to this time, the two criteria predominantly used for defense systems evaluation and selection were "performance and schedule". These criteria were used to evaluate a system on its ability to combat a foreseen threat (performance) and whether it could be developed and deployed in a time considered reasonable to meet that threat (schedule).

In January 1961, Robert McNamara became Secretary of Defense. During his first year in office, he decided to centralize the authority and planning for the defense establishment at the level of the Office of the Secretary of Defense and to decentralize operations. He acted in order to improve the defense planning process by instituting the following:

1. Planning-Programming-Budgeting System (PPBS)
2. Five-year Defense Plan (FYDP) and
3. Use of system cost-effectiveness analysis in the defense decision-making process.

The initial concepts developed during the 1960's to control military acquisition cost grew from Secretary of Defense McNamara's systems analysis efforts. The first control technique which ensued was that of cost-effectiveness analysis. This technique was utilized to systematically quantify both the costs and benefits of decision alternatives. Studies were termed "cost benefit" if the identifiable benefits could be measured in dollar values. Alternatively, those analyses which could not reduce benefits to quantifiable dollar values become known as "cost-effectiveness" analysis.

The second technique which evolved from the increased interest in cost control was life cycle cost analysis. This concept emerged conceptually during the mid-1960s. The innovative concept of LCC was that ownership cost would be

considered with acquisition and development cost in the weapon system selection decision. The identification of the ownership cost was of particular importance when it was considered that in many weapon systems the "ownership" costs over the life cycle far exceeded the initial acquisition costs of the system itself.

Two other techniques have since evolved. The first, Design-to-Unit Production Cost emphasizes the importance of designing systems in a manner which minimizes their unit production cost. The shortcoming of this technique is that its focus is on control of acquisition costs, perhaps without regard to the future costs of ownership of the weapons system.

The second technique, Design-to-cost(DTC) was developed to acknowedge the importance of ownership costs and the impact that design decisions played on these future costs. Design to cost is a concept of management wherein stringent cost objectives are established during system development. Management then strives to meet these objectives by practical trade-offs between development schedule, performance, operational capability and cost itself. In the design to cost concept, cost is a design parameter and is continually addressed. It is considered an inherent part of system production and development [Ref. 11: p. 2]

DTC focuses on all acquisition and O&S costs of the LCC equation except R&D. An acquisition DTC goal is expressed in the form of flyaway (rollaway, sailaway) costs. DTC O&S goals may be expressed in dollars or other measurable factors, (e.g., reliability, maintainability, manpower)that are design-controllable and which significantly affect O&S costs and can be measured during test and evaluation. [Ref. 22: p. 4-55]

Only LCC analyses provide for estimation and control of all three phases of a system's cost-development, investment,

and operations and support. Utilization of LCC techniques in an acquisition can help avoid suboptimal emphasis on production costs at the expense of future operating costs. However, implementation of these techniques has been slow and the use of LCC as a design parameter has met with varying degrees of success. [Ref. 13: p. 4]

C. USES OF LCC INFORMATION

The LCC estimate has many and varied uses. Seldon [Ref. 14: pp. 11-12] lists six primary uses of LCC :

1. Long range planning
2. Comparision of competing programs
3. Comparision of logistics concepts
4. Decisions about the replacement of aging equipment
5. Control over an ongoing program
6. Selection among competing contractors

In addition, May [Ref. 10: pp. 2-3] lists the following uses of LCC estimates :

1. Support of budget estimates
2. Design-to-Cost(DTC) program
3. Management reviews

These uses all equate to one common purpose : LCC aids decision makers by supplying information to assist in the decision process. Thus, life cycle costing is really a continuous management process the object of which is to ensure that new acquisitions meet operational needs at the lowest life cycle cost. [Ref. 15: p. 1]

D. WEAPON SYSTEM LIFE CYCLE STAGES AND COSTS

Blanchard [Ref. 18: p. 5] gives the concept of the life cycle as follows:

A system, to be useful, must satisfy a need. However, designing a system to just meet the need is not usually sufficient. With few exceptions, the system must be able to continue to meet the need over a specific period of time in order to justify the investment in time, money, and effort. Thus one must consider a system in a dynamic sense.

Specifically, for a weapon system, the life cycle is the period which begins with threat analysis and the need for the weapon system, and ends with its disposition.

Figure 3.1 [Ref. 19: p. 3] graphically portrays the relationship of LCC to the weapon system life cycle. The dotted lines approximate the periods during which cost-influencing decisions are made.

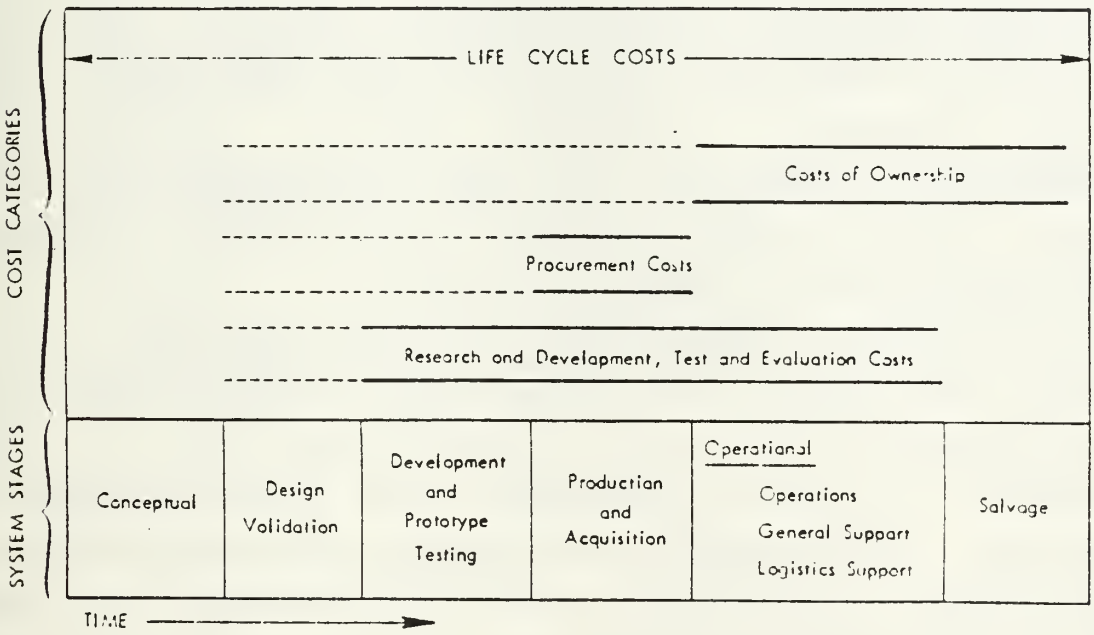


Figure 3.1 WEAPON SYSTEM LIFE CYCLE STAGES AND COST.

1. Conceptual-This phase includes investigations into weapon system design feasibility and planning by service, government, and contractor personnel. Important outputs

from conceptual studies are initial estimates of weapon system acquisition and operational costs.

2. Design Validation-This stage consists of the specifications of the desired performance and physical parameters of the weapon system, additional research and development and preliminary cost estimates. The request for proposal(RFP) is prepared and distributed to potential candidate contracters. Responses to the RFP are processed and the individual proposals are evaluated by the procuring agency. Improvement products from this stage are the prototype designs, and fabrication and testing of the basic design.

3. Development and prototype testing-The basis for full-scale production are established during this phase. A specified number of prototypes are constucted, tested and evaluated. Additional R&D for product improvement takes place. Pursuant to successful testing, the design for production go-ahead is given for the prefered prototype design. The prototype testing can include several competing designs from two or more contractors.

4. Production and Acquisition-Duing this stage, fabrication and testing of one or more of the production-configuration systems of the selected design take place. The contract for a series production of the required quantities is made. Additional R&D for necessary system and component improvement is carried out. Estimations for initial spares requirements are also made.

5. Operational-In this stage the weapon system is utilized and maintained for its primary mission. Support equipment and spare parts are also purchased, utilized and maintained. This stage generally lasts 10 years or more for major weapon systems.

6. Disposal or Salvage-This phase entails the removal, disposal or conversion (through modifications) of the system to another mission function.

Given the above chronological sequence of phases, We can associate with one or more stages various military costs for: research and development, production or procurement, ownership, and salvage. The summations of these costs are the life-cycle costs for the weapon system. The following paragraphs list definitions for each categories. [Ref. 10: pp. 2-1,2]

1) Research and Development are those costs associated with the research, hardware and software. More specifically, it includes the cost for feasibility studies, simulation or modeling ; engineering design, development, fabrication, assembly, and test of prototype hardware , initial system evaluation , associated documentation, and test of software.

2) Production are those costs associated with producing the aircraft, initial support equipment training, technical and management data, initial spares and repair parts, plus many other items required to introduce a new system to the field.

3) Operating and Support is the cost of personnel, material and facilities of both a direct and indirect nature required to operate, maintain and support the hardware and software of the system.

4) Disposal is the cost associated with demilitarizing or otherwise disposing of a system at the end of its useful life, minus any salvage value. This category is seldom estimated in most analyses. Often this value is very small in comparison to the other categories. The aircraft could be placed in storage at the end of their useful life.

E. RELATIONSHIP OF DEVELOPMENT COST IN SYSTEM LIFE-CYCLE COST

In practice, life cycle cost estimates can be a powerful tool for indicating the size and relative amount of resources required for the development, production and operational phases of a system. The greatest value from life cycle costing will result when it is used early in a system life cycle for the basic program decisions on requirement and designs. This fact is graphically illustrated in Figure 3.2. [Ref. 22: p. 1-8]

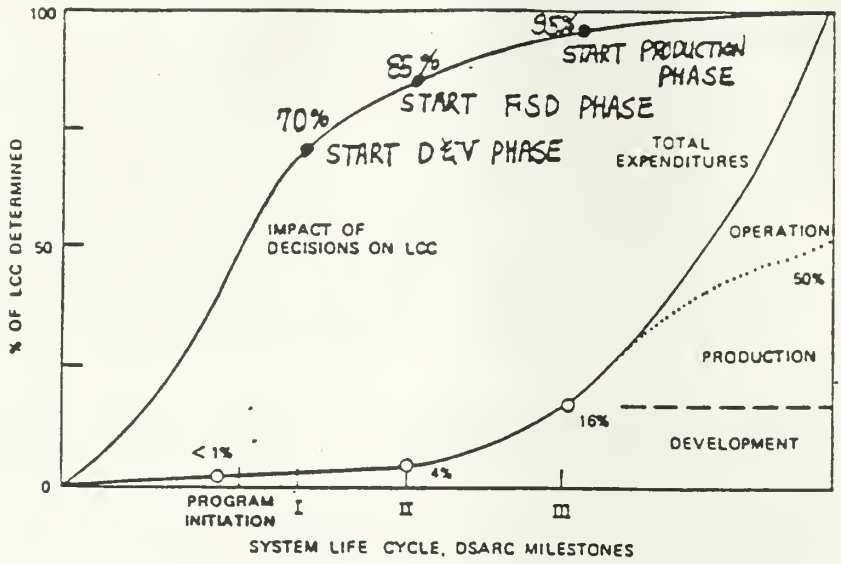


Figure 3.2 TYPICAL WEAPON SYSTEM LIFE-CYCLE COST.

As indicated in Figure 3.2, over 70% of the life cycle costs of a system are determined early in the life cycle and prior to the time the Secretary of Defense approves the start of the Demonstration and Validation phase. These decisions would have been made on the basis of conceptual design studies and the statement of required operational capability provided by the operating command. Key cost drivers include performance, operational environment, reliability, logistics concept, the extent of use of Military Specifications and Military Standards and the procurement or competitive approach during the acquisition process.

Roughly 85% of the LCC are frozen before the Full-Scale Development phase begins, when only a small percentage of the total system cost has been expended. Also, around 95 percent of the LCC are determined by the end of Full-Scale development. A little more money spent in the early stages of the program can save a great deal of money over the life the system [Ref. 22: p. 1-8]. Figure 3.2 emphasizes the importance of fully considering life cycle costs early in the life cycle.

IV. THE KEY FACTORS AFFECTING LIFE CYCLE COST

This chapter will identify those factors that affect LCC. Concentration on these factors early in the system's acquisition process will either in cost reductions or provide the rationale for necessary tradeoffs.

A. PERFORMANCE REQUIREMENTS

For years the achievement of higher performance, regardless of costs, has guided weapon system development. Failure to consider cost permitted essentially unrestrained performance specifications which in turn impacted both acquisition and support costs tremendously. A recent Boeing aerospace study noted, for example, that an increase in the design Mach number of a transport aircraft from .5 to .8 resulted in corresponding increase in maintenance manhours per flying hour from 12 to 19. Similarily, an increase in the design Mach number of bomber aircraft from .8 to 2.0 generated a maintenance manhour per flying hour increase from 26 to 55, while a like increase in the design Mach number for fighter/attack aircraft from 1.9 to 3.5 increased the required maintenance manhours per flying hour from 20 to 250 [Ref. 23: p. 5]. The cited examples illustrate the tremendous impact of an increase in just one performance requirement on the support cost of a weapon system. Add to that requirements for increased accuracy, maneuverability, time to climb, reaction time, etc. and life cycle costs soon begin to go out of sight. The need to challenge such requirements at the very outset of system development is clearly evident. Serious cost tradeoff analyses must be performed in order to properly assess the affordability of increased performance requirements.

B. RELIABILITY

Because of its impact on both weapon system effectiveness and life-cycle costing, reliability plays a key role in trade offs these two parameters. While effectiveness increases directly with reliability, the life-cycle cost/reliability relationship is not so simple. Figure 4.1 illustrates the classical relationship between these latter two variables where reliability in this case is quantified in terms of Mean Time Between Failure(MTBF). [Ref. 24: p. 5]

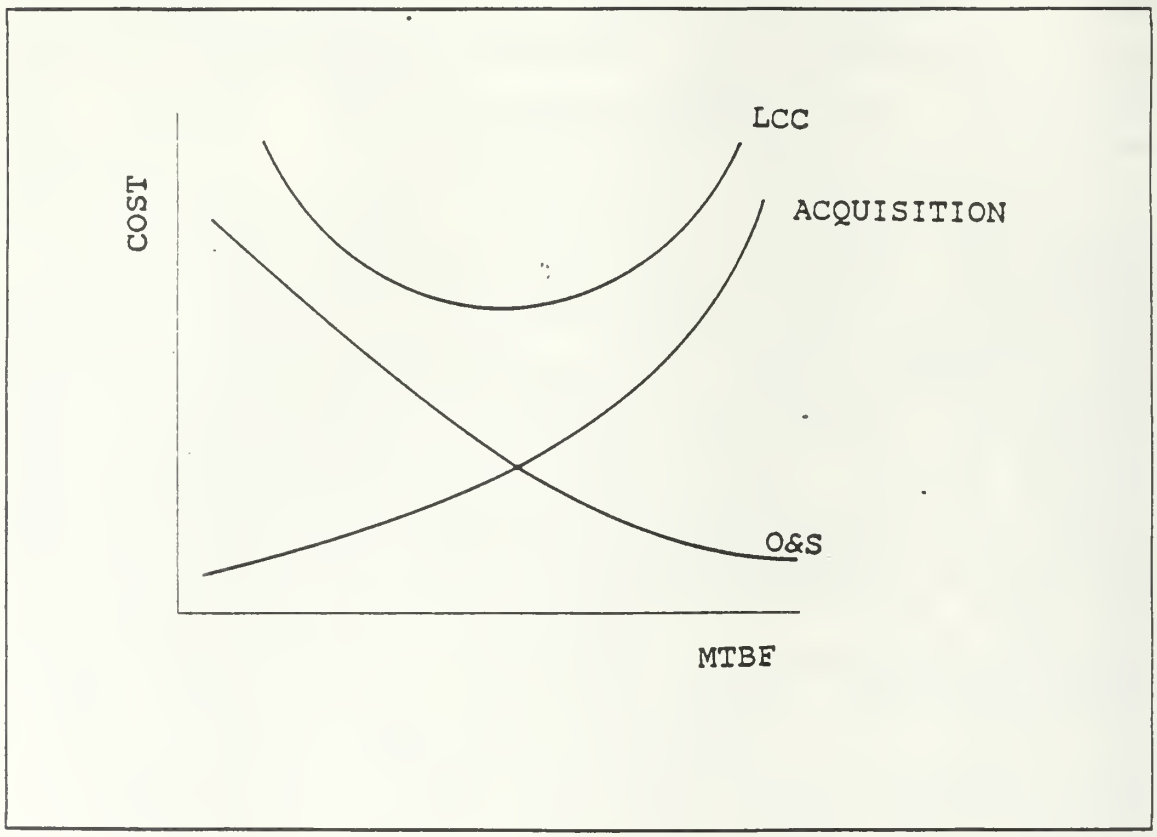


Figure 4.1 LCC / RELIABILITY RELATIONSHIP.

As the figure illustrates, increasing MTBF drives down support costs but is achieved only with increased acquisition costs. By definition, the life-cycle cost curve is

the sum of the acquisition and support cost curves. Examination of this curve reveals that the optimal life-cycle cost is achieved at the MTBF which corresponds to the low point on the LCC curve. Decreasing or increasing MTBF from that point will drive up life-cycle costs. While it should be pointed out that this "classical" relatonship may or may not be applicable to individual weapon systems, it does illustrate a common relationship.

An addtional relationship results from the so-called "force multiplying effect." [Ref. 25: p. 11]

For example, if the reliability of a particular weapon system can be increased by 25% through improved design practices,this improved reliability produces the same operational effects as having a 25% increase in the number of those weapon systems available to accomplish their mission, and at little if any additional support cost. The alternative is to buy more systems.

System-wide acquisition costs, then, decrease with the reduction in the number of required buys.

C. MAINTAINABILITY

Maintainability impacts life-cycle costing in two ways. First its impact on the availability of a weapon system to perform the assigned mission has the same force multiplying effect as reliability. Perhaps its greatest impact, however, is in the area of manpower costs. The maintainability of a weapon system as determined by its complexity, access to equipment, trade off between field and depot level maintenance, etc. determines the number and skill levels of personnel required to operate and maintain it. These factors also impact the size and structure of training programs needed to provide manpower to support the system

Maintainability must be addressed early in the design of the system. Designs which provide easy equipment access, abundant diagnostic information, and reduced complexity will yield substantial support cost dividends.

D. COMPLEXITY

While the complexity of a system may seem directly tied to performance requirements, a thoughtful analysis reveals that the connection is less direct. Simplicity of design normally produces reduced acquisition and support costs.

In attempting to quantity "complexity" the Boeing study cited earlier concluded that complexity was a function of the number of parts in the system. Fewer parts generated reduced development costs, reduced production costs, and reduced operating costs [Ref. 23: p. 4]. Fewer parts require fewer production steps, tools, spare inventories, and drawings ; hence, lower costs result.

E. STANDARDIZATION

The idea of standardization is directly related to the concept of complexity stated above. Standardization within systems allows for less unique parts and/or less one-of-a-kind subsystems which in turn precipitate less costs for the reasons stated above. Standardization of subsystems also permits the centralization of depot repair facilities with attendant reductions in support costs.

The development of the F-16 provides a splendid example of dividends resulting from attention to standardization principles. Some 254 components on the F-16 are identical to those on the other aircraft while an additional 78 are modifications of such components. Across the aircraft itself such features as ambidextrous horizontal tail surfaces and flaperons, 80% commonality of right and left landing gear parts, and use of a single electro-hydraulic servo in five different locations in the flaperon system further illustrate the results obtainable from a standardization conscious design effort. [Ref. 23: p. 16]

F. TECHNOLOGY

Technology can serve as master or servant in the development of a new weapon system. In the latter role, introduction of technology innovations into the design can reduce both acqusition and support costs.

Technology can become a harsh master,however, when new untried technologies are introduced to meet increased performance requirements, or when the designer falls prey to the "because we can, we must" syndrome(technological imperative) [Ref. 27: p. 4]. In these roles the new technologies first push up acqusition costs, then return later with hidden support costs that reveal themselves only with age and use. Effective defenses against such cost increasing tendencies include extensive, realistic testing to provide a broader understanding of the new technology and the disciplined tailoring of the technology to realistic requirements.

V. THE LIFE CYCLE COSTING IN ACQUISITION PROCESS

This chapter provides a basic knowledge of the acquisition process and the ways life cycle costing may be used throughout the acquisition process of a weapon system. The program manager may use life cycle cost concepts throughout the acquisition process for a major program

The U.S. DoD Directive 5000.1 defines four distinct phases of the acquisition process: concept exploration, demonstration and validation, full scale development, production and deployment phase. The four phases are separated by decision milestones.

It is not necessary for every system to move through each phase one by one, nor is it unusual for a system development to begin at any of the phases prior to or at the production and deployment phase. Figure 5.1 is a summary overview of the acquisition process. [Ref. 22: p. 1-18]

A. PROGRAM ORIGINS, MISSION AREA ANALYSIS(MAA)

The starting point for a major system originates in many sources. The need may arise from a perceived or changed threat, from obsolescence of existing systems, or from a technological or cost reduction opportunity. Ideally the mission need would originate from a situational summary, a document which discusses weaknesses of an operational plan as experienced during trial maneuvers or exercises of a Unified or Specified Command.

B. CONCEPT EXPLORATION PHASE.

The first phase for a major system is the concept exploration phase. It is during this phase that the program manager is assigned, and several alternative concepts or methods to accomplish the mission are considered. At the end of this phase, Milestone I, a decision is made by the

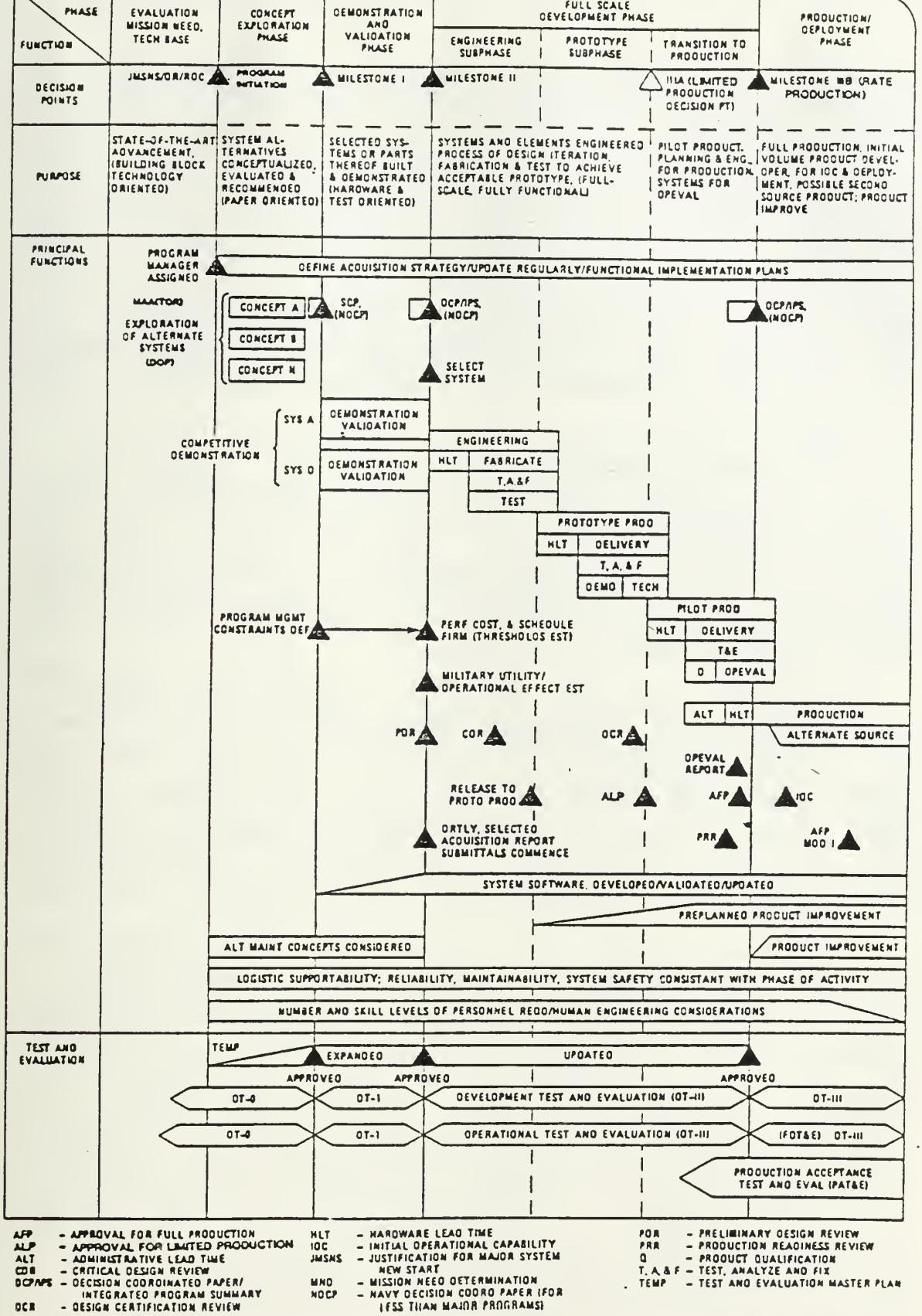


Figure 5.1 SUMMARY OVERVIEW OF THE ACQUISITION PROCESS.

reviewing committees/groups to select the alternative or to request further development in the ensuing phase. Alternative concepts for achieving the mission need may be solicited from R&D laboratories, universities, or industry [Ref. 22: p. 1-14]. This phase is extremely critical so far as determining the system's future cost. As pointed out in Chapter III, the activity during this phase determines over 70% of the life cycle costs of a system. Therefore, making the right decisions during the conceptual exploration phase is crucial. [Ref. 33: p. 36]

A very small amount of money spent over a short period of time during this phase has a significant effect on the system's performance and cost for the rest of its life cycle. Wrong decisions create problems. Solutions to those problems later in the program life cycle require much large expenditures of resources and time.

This phase involves tradeoff studies of competing concepts capable of satisfying operational needs. Of necessity, these concepts start out on a broad scale and then become more narrowed and more explicit as the concept exploration phase progresses. Premature introduction of operating and support details may have a negative effect by closing out promising alternatives. [Ref. 34: pp. 9-10]

During this phase, life cycle cost models should be generalized and concentrate on the types of support alternatives and functional environments the actual operational system will see. They should merely provide an analytical framework for the conceptual studies and support key tradeoff decisions. The program model should be structured so as to identify the relative life cycle cost impacts of system alternatives. It should identify only those major characteristics that drive the major system costs. Detailed cost information, such as provided by accounting models, is of little utility during this phase. [Ref. 35: p. 10]

C. DEMONSTRATION AND VALIDATION (D&V) PHASE

This is a key phase as it verifies the ability of the design to meet mission needs. During this phase, the alternatives selected from the concept exploration phase are to be demonstrated, either by analysis or actual prototype design in order to verify the capability/availability/credibility of the critical aspects of the system design. Prior to the next phase, decisions are made to select the best alternative for further development. [Ref. 22: p. 1-14]

The D&V phase is pivotal in the acquisition process. Dollar expenditures during this phase represent only about 3% of the system LCC. However, since expenditures in the succeeding phases are largely determined by the decisions made in the D&V phase, the cost/risk/performance tradeoffs made during this phase will have a marked impact on LCC. [Ref. 22: p. 3-30]

Life cycle costing activities during this phase become more detailed. The Integrated Logistics Support(ILS) plan forms a convenient reference for operating and support concepts. Logistics support constitutes a principal design parameter with the magnitude, scope, and level of this effort by the contractor consistent with other D&V phase activities. [Ref. 14: p. 4]

During this phase, the Sevices must provide the contractor with proposed maintenance plans, flight profiles, basing plans, number of aircraft at each base, and logistics data which can be used for LCC tradeoffs. [Ref. 35: p. 4] Based on the extent contractors' can identify data needed to construct a life cycle cost model, the life cycle cost model begins to take form. Both the program office and contractors use the model as a management tool.

At this point in the program, life cycle costing should become at least a subconscious influence if not a conscious

influence on all program activities. The key challenge to the use of LCC model during this phase of a program's development is to relate specific design tradeoffs to resultant O&S costs. The data base for LCC model represents best available planning information provided by Air Force Logistics Command(AFLC) from similar systems in the inventory. The model might be used in any of a number of tradeoffs. A typical one might be determining the level of design in an electronic component which will be removable and replaceable at base level. This decision is intimately related with the optimum repair level analysis, reliability and maintainability data, environmental data and logistics suport data and is all integrated by the life cycle cost model. [Ref. 37: p. 6]

As this phase proceeds, the program office and contractors identify deficiencies in the LCC model in terms of both how it is constructed and the adequacy of its data. Thus the LCC model evolves as the system evolves.

D. FULL-SCALE DEVELOPMENT PHASE

Full-Scale development is considered to include three sub-phases for completing the design and verifying its effectiveness through testing. The sub-phases are detail engineering, prototyping and a pilot production sub-phase. This phase is important for several reasons. During this phase, a production contractor is selected and the second source, if high-volume production is planned, is selected. Prior to selecting a second source, the strategy for second sourcing must be firmly developed as requirements(data,etc.) for the second source must be obtained through previous contracting. In this phase, prior testing culminates with the signing of approval for full production(AFP) prior to proceeding to the next phase.(AFP may soon not be required.) [Ref. 22: p. 3-36]

At the conclusion of full scale development, the program should be ready for production of operational hardware. This requires the full-scale development phase to resolve all technical as well as cost risks remaining in the program. Early in this phase, the LCC model will have become sufficiently mature to serve as an aid in selecting contractor sources.

If life cycle costing is a source selection factor, the Government should advise the bidders of the basis for the Government's evaluation. In addition, for both completeness and fairness, the Government should provide contractors specific operational scenarios that form the basis for the cost model. These scenarios should include deployments, operational concepts, maintenance and resupply planning, assumptions and constraints, etc. Government reliance on contractors' life cycle cost estimates should probably ignore those cost factors provided or imposed by the Government which are common to all bidders. These may include Government furnished subsystems, fuel,weapons, etc. [Ref. 38: p. 1]

A means of motivating the contractor to develop a system with the lowest reasonable life cycle cost is to include contractual provisions for award fees based on demonstrated improvements in failure rates and reliability during prototype testing.

Both the Government and the contractors are still dealing with uncertainty about future O&S costs. Each party must recognize these uncertainties. The program manager would continue to use the LCC model during this phase. The model would be even more detailed than in earlier phases and include award fee and warranty options. Its utility in day-to-day decision making expands as the program progresses. Both the Government and the contractor can exercise the model at the subsystem or major assembly level to determine

the relative effects of design alternatives on life cycle costs. But a model is just a model. It only represents the real world. Because of uncertainty and lack of detail, it is not the real world. Therefore, the Government needs some means to verify, before the production phase, those performance chracteristics of the system that make up the largest share of the operating and support costs. One method of determining these characteristics of the system is through testing pre-production prototypes. A key contribution of this early testing to improving cost estimates is the indication of relative sensitivity of life cycle costs to various cost factors. For instance, the sensitivity of tradeoffs between the number of spares in the supply pipeline and the system or subsystem mean time to repair can be estimated in terms of life cycle costs. [Ref. 38: p. 22]

E. PRODUCTION AND DEPLOYMENT PHASE

This is the most costly of all the phases. During production and deployment phase, the system is assembled in accordance with previously developed documentation and put into use by the particular Service. For high-volume production, second sourcing, in accordance with the previously designed strategy, is normally used during this phase. For low volume production, where the systems are highly sophisticated, it may be desirable to second source subsystems or components. [Ref. 22: p. 1-16]

Those decisions affecting 95% of the life cycle costs already will have been made [Ref. 33: p. 36]. The basic objective of life cycle costing may or may not been achieved; that of reducing the cost of ownership of weapon systems. Yet even at this point in the life of a program, the life cycle cost model continues to have utility. The primary contractual activity during this phase of the program is the award of a production contract. Life cycle cost models may play a major role in the procurement

process. As a hedge against uncertainty, one possibility is for the Government to include a provision in the production contract to adjust the award fees based on whether the contractor exceeds or fails to meet the life cycle cost criteria which formed a basis for the contract award. The philosophy behind such a provision is that the contractor should share in both the cost risks and the rewards associated with the O&S costs of the equipment they provide. [Ref. 36: pp. 3-4]

An additional way to reduce risk for the Government in production contracts is to include provisions for various types of warranties or contractor guarantees for field reliability and performance. The Government would then share any savings with the contractor or hold him responsible for any shortfalls in system performance. [Ref. 29: p. 25]

The common purpose of each of these possible contract provisions is to provide a means to motivate the contractors to do a good job in the beginning in terms of life cycle costs and, if they fail, have them share or even fully absorb the additional costs.

As a result of the testing of initial production articles, actual cost data can be inserted into the life cycle cost model and replace the predicted data that had been used up to that point in time. Of particular importance is the base level O&S costs which form the foundation for future use of the LCC model.

An initial use of the LCC model during the deployment phase will be to verify the adequacy of the maintenance data collection system used for that particular weapons system. During this phase, the LCC model is updated and refined to use as a management tool for key logistic support and modification decisions. Thus, the LCC cost model appears to have utility throughout the life cycle of the system. [Ref. 11: p. 5]

The potential utility of life cycle costing extends throughout the concept exploration, demonstration and validation, full-scale development, production and deployment phases of the system [Ref. 11: p. 6]. The life cycle cost model is constantly refined and updated. Hopefully, it will have served its primary purpose as a management tool for reducing the total cost of ownership of a system and reducing some of the uncertainty inherent in the decision making process during system acquisition.

VI. METHODOLOGY FOR LIFE CYCLE COST ANALYSIS

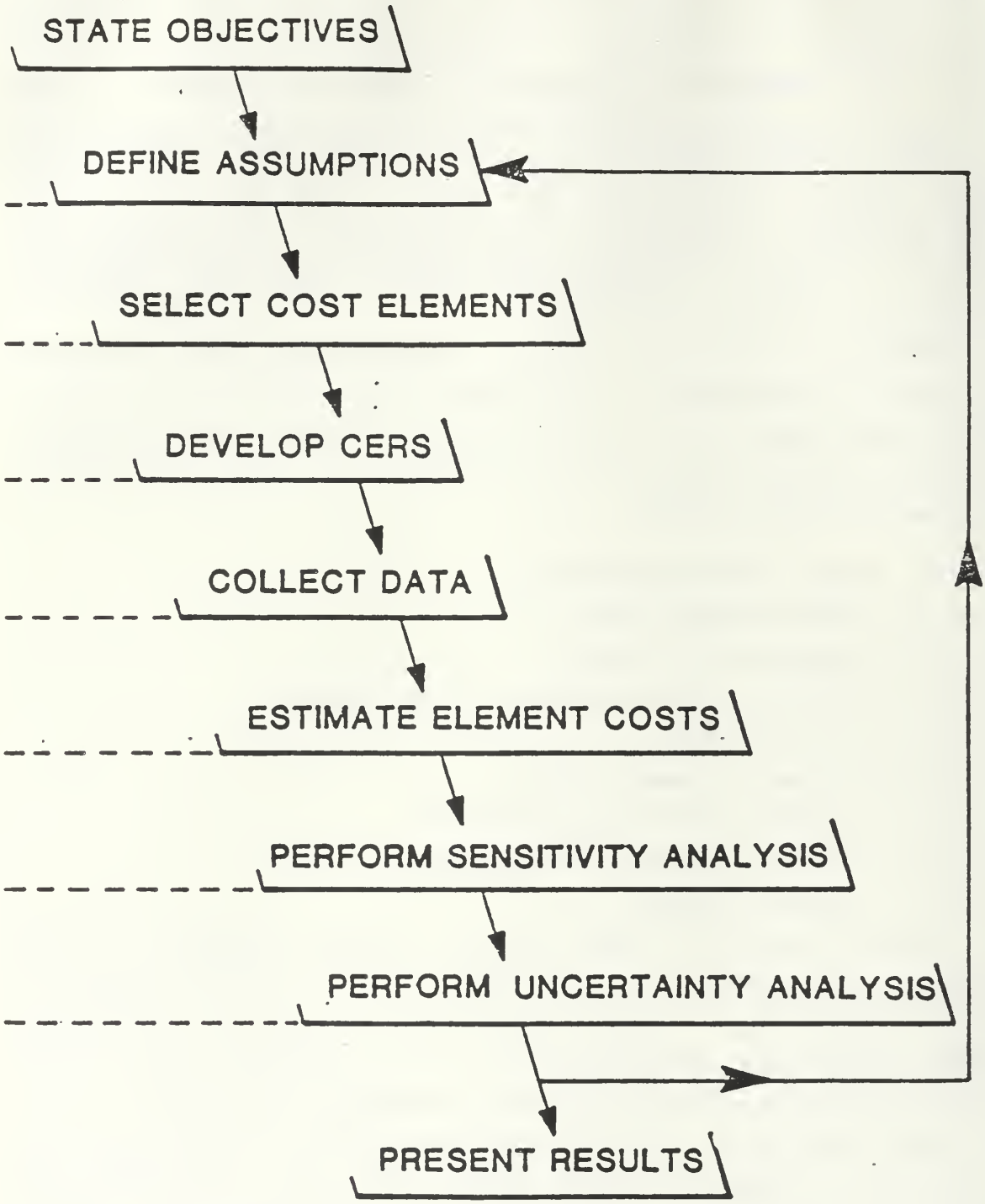
This chapter presents a general methodology that should be followed in estimating life cycle costs for use in any cost analysis of weapon system acquisition. The methodology that the analyst follows draws heavily upon the material presented in Ref. 13 and Ref. 41.

Figure 6.1 shows the typical methodology that should be followed in performing an LCC analysis [Ref. 41: p. 49]. The methodology may be viewed as a flowchart which depicts the organization required to produce an LCC model. The steps in the methodology are:

1. State study objectives
2. Define assumptions
3. Select cost elements
4. Develop cost estimating relationships
5. Collect data
6. Estimate element costs
7. Perform sensitivity analysis
8. Perform uncertainty analysis
9. Present results

These nine basic steps are not a serial process, rather they are interdependent and interactive. Most LCC analyses will include these general procedures in greater or lesser detail dependent upon analytical requirements. Each step will be briefly discussed in the following sections.

The life cycle cost estimates are usually organized in tabular or graphical from to serve as inputs along with the results of system effectiveness analyses to cost-effectiveness studies. They are also useful as inputs to reports containing independent cost estimates and to many other kinds of management planning efforts.



NOTE: It is important that these steps be documented

Figure 6.1 LIFE CYCLE COSTING METHODOLOGY.

1. State analysis objectives

The first step of the methodology is to identify, formulate, or state the analysis or study which originally generated the need for the cost estimating exercise. Properly identified objectives will help to define and limit the scope of the cost analysis effort.

2. Define assumptions

The adoption of valid assumptions that underlie the estimating process in life cycle costing is critical if the exercise is to yield useful results. Assumptions are often necessary to make the abstract cost model more representative of the proposed real world, because all specific detailed inputs are not always available, particularly for "far-out" systems. The adoption of assumptions allows the analyst to set parameters around uncertainties and proceed with the analysis.

It is important that the assumption be formulated by those personnel closest to and most experienced in the areas in question-- typically not the analyst himself. As an example, logistics personnel should formulate the support concept assumptions and acqusition strategies should come from the Program Manager.

Typical assumptions for systems/equipments LCC analyses are as follows.

a. Procurement quantity
b. Rate of production
c. Concept of operation
d. Logistics support concept
e. Life of the equipment/system
f. Residual value
g. Disposal costs
h. Rate of inflation

i. Rate of discounting

j. Sunk costs

3. Select Cost Elements

The identification of cost elements is an important step. It involves the listing of all program costs into a structure which provides assurance that all major costs are accounted, that costs are not doubled and that the cost elements are consistently and clearly defined. Cost elements for sunk cost categories need not be considered.

4. Develop Cost Estimating Relationships

The procedure for estimating each cost element must be specified in this step. The analyst can select a parametric, an engineering, analogy or subjective CER for the cost model. Cost estimating techniques will be briefly discussed in following chapter. The availability of relevant data at the point in time when the analysis is conducted will influence this step. As the acquisition process progresses, the mixture of cost estimating procedures selected for analysis will usually shift from the use of CER's to the use of actual costs.

5. Collect data

One of the greatest problems in estimating life cycle costs is the collection and validation of data. The data required for the analysis are often not available, particularly during R&D the phase. Even when data are available, they may be in a format unsuitable for the analysis at hand.

Data collection represents perhaps 90 percent of the total work effort in LCC analysis. The DoD Instruction 7041.3 suggests the folowing data sources: established reports, opinions and judgement of experts, observation and tabulation of steps in a work process, outside organizations, and information centers.

6. Estimating Element Costs

After the necessary input data have been collected and validated, estimates of element cost can be obtained through the use of relevant CER's. The analyst should also estimate the degree of cost uncertainty This could be expressed statistically through confidence intervals or through pessimistic, most likely, or optimistic estimates.

7. Perform Sensitivity Analysis

The sensitivity analysis aids the analyst in determining uncertainty in life cycle cost estimates. The intent is to (1) determine the sensitivity of certain input parameters to the analysis results,and (2)to assess the risk and certainty associated with a given decision;i.e., the probability of making a wrong decision. In essence, the analyst needs to address the "what if" questions in an attempt to minimize the risks associated with given decisions. [Ref. 28: p. 96]

Sensitivity analysis is generally performed at two differant levels of estimation. The first is at the cost equation or CER level. At this level, sensitivity analysis attempts to describe the possible effects if a developed CER fails to "capture" or accurately describe that element of cost which it is attempting to estimate. The second level of sensitivity performance is on the aggregate total LCC. Here sensitivity analysis helps define the cost effects of all CER's if they interact in a manner which produces an inaccurate over-all estimate of true system cost. This sensitivity of the total estimate is important since errors in individual CER's may be additive in one direction or other inter relationships may be disguised by offseting errors.

Sensitivity analysis is frequently used to define likely costs in the O&S area if performance trde-offs are made. For example, "what would be the additional O&S costs

incurred over a system's life if mean time between failure (MTBF) specifications were lowered by "x" amount for the equipment?" This technique is a valuable tool which informs management of the cost associated with various alternatives and, more importantly, the possible costs associated with errors in either cost estimaton or the defined assumptions. [Ref. 28: p. 98]

8. Perform Uncertainty Analysis

In accomplishing a life cycle cost analysis, there are many areas where risk and uncertainty can be introduced, and the more that this occurs the less valid the analysis becomes. Hence, although the various aspects of risk and uncertainty can not be eliminated altogether, it is the intent to minimize such to the greatest extent possible [Ref. 28: p. 99-100]. Uncertainty analysis is especially important with large acquisition cost elements such as unit production, and to important O&S cost contributors such as personnel and depot maintenance. In the very early stages of product development(when uncertainty is greatest) it should at least be possible to bound a most likely estimate with a high and low variant. The high and low estimates should preferably reflect actual cost experience with other systems or equipment or be based on the outcome of certain events or policy decisions rather than being arbitrary percentage adjustments to the original estimates. As the effort proceeds further into the acquisition phases, more thorough uncertainty analysis should be possible. Description of uncertainty as a probability distribution(often subjectively derived) is widely and effectively used practice. In summary, a LCC is simply incomplete if no attention is paid to uncertainty analysis. [Ref. 41: p. 48]

9. Present the LCC Estimate

A properly completed LCC analysis will identify those costs associated with the unique situation defined by the objectives of the study. It is a result highly dependent upon the specific assumptions associated with those stated objectives. Therefore, it is imperative that the cost estimates always be closely associated with the study from which they are drawn.

The actual format of an analysis can take many shapes, dependent upon its intended recipient, but should as a minimum, describe individual cost elements and cost categories by both annual and total costs. [Ref. 30: p. 5]

In addition the estimates should be presented in an escalated, deescalated and constant year dollar format. The overall format of presentation is specified by the overlying cost analysis instructions.

VII. TECHNIQUES AND CONCEPTS FOR COST ESTIMATING

A. COST ESTIMATING TECHNIQUES

This chapter examines three of the generic techniques used in cost estimation after the term "cost estimate" is first defined.

The Defense Systems Management College uses the following definition. "A cost estimate is an opinion concerning expected cost." The estimate is a professional opinion based upon a specific set of ground rules. The estimate must be for a cost that will ether be incurred in the future or for a cost that cannot be reasonably isolated from historical data, i.e., the actual costs are not known. Finally, it is important to note that estimates are expected to change over time as more knowledge is gained about the system and how it will be operated and maintained once delivered to the user. [Ref. 10: p. 3-1]

The three most often used cost estimating techniques in DoD are analogy, engineering estimation and parametric estimation. Analogy is, perhaps, the simplest of the three. The analyst begins by identifying an existing system that is similar to the system of interest. The cost of the system of interest is then estimated by taking the cost of the existing system and adjusting it to account for differences between the two systems. Although widely used, analogy has several limitations. Analogy places heavy reliance on the opinion of experts to determine the similarities and differences between the two systems. Two experts, given the same information, often have different opinions. Thus, the analysis may not reproducable, may not be traceable, and may be difficult to document. On the positive side, estimates using analogy are usually fairly easily and quickly done. Analogy is used mainly in the early stage of weapon systems development when the least is known about the final end product.

The second estimating approach is the "grass roots" or engineering method, also known as the bottoms-up approach. The analyst begins at the lowest level(highest level of detail)and works up adding costs as they occur. Traditionally, weapon system cost estimates have been prepared using industrial engineering techniques. These techniques involved detailed studies of operations and materials required to produce the new system. The cost estimates frequently require several thousand hours to produce with voluminous supporting documentation. Changes in design require extensive changes in these estimates.

In spite of all the time and effort involved in preparing these estimates, there is considerable uncertainty remaining. This is evidenced by the large cost overruns cited by the annual General Accounting Office(GAO) reports to Congress. Several consequences of these over-runs have been :

1) A decrease in the public's confidence in the managerial ability of military leaders.
2) Acquisition of weapon systems that were not cost effective.
3) Forced reductions in the number of units purchased in order to stay under an imposed ceiling on the weapon system's acquisition cost.
4) Financial hardships experienced by military contractors in trying to meet unrealistic price estimates.

Within the last decade, a third major approach to cost estimation has come into prominence. Independent parametric cost estimation has received considerable attention in DoD as a means of increasing the accuracy of cost estimates. Parametric estimation is a technique using various mathematical processes, such as regression analysis, to develop a Cost Estimating Relationship (CER). A CER is simply a mathematical equation that relates one or more characteristics of the system to cost. It is a function of one or more independent variables which yields cost as a dependent variable [Ref. 16: p. 46]. The equation can be simple or complex, linear or non-linear.

Data requirements for parametric estimating are extensive. The cost estimator must recognize which variables have a valid relationship to cost. Once developed, CER's must be continually updated and refined as new data are obtained. The new data add to the data base allowing the CER to become more useful. It is evident that CER's may be constrained by the need for a suitable data base of similar systems. Although parametric analysis may be used through the acquisition cycle, it must be used extensively during the conceptual and validation phases.

Parametric costing is thought to be more reliable than analogous costing. The reason is most likely more a function of definition and use than fact. [Ref. 17: p. 15]

Although parametric cost estimation procedures are preferable in most situations, there are circumstances when analogy or industrial engineering techniques are required because the data do not provide a systematic historical basis for estimating cost behavior on a combination. [Ref. 17: p. 7]

In conclusion, in any situation the estimating procedure to be used should be determined by the data available, the purpose of the estimate, and, to an extent, by such other factors as the time available to make an estimate. The essential idea to be conveyed in this section is that, when properly applied, parametric cost estimation procedures are varied and flexible enough to be useful in most situations that ROK military analysts are likely to encounter. Although no specified set of procedures can guarantee accuracy, decisions must be made. It is essential that they be based on the best possible information. The analyst must seek the approaches that will provide the best possible answers, given the basic information that is available. [Ref. 17: p. 9]

B. GENERAL BASIC CONCEPTS TO ALL COST ESTIMATES

This section discusses discounting, inflation, and the learning curve within the context of life cycle costing.

1. Discounting

The rationale behind discounting future cash flows is the realization that the deferral of expenditures allows the present use of money in alternative investments to yield some beneficial returns. If the funds must be expended in the present, their use in alternative investments is lost. DoD Instruction 7041.3 prescribes the present DoD policy for the use of discounting(or present value analyses) for the economic analysis of DoD programs. At the present time the standard discount rate, specified by DoD, is ten percent per year compounded annually. [Ref. 13: p. 46]

The discount factor, for year n and discount rate R, is calculated as follows:

$$\text{Discount factor} = 1 / (1+R)^{n}$$

The present value of any future cost can be obtained by multiplying that cost by the applicable discount factor.

2. Inflation

When developing time-phased cost profiles, the aspect of inflation should be considered for each future year in life cycle. During the past several decades, inflation has been a significant factor in the rising costs of systems and equipments and in the reduction of purchasing power of the dollar. Inflation is a rather broad term covering the general increases in the unit cost of an item or activity, and is primarily related to labor and material costs. [Ref. 28: p. 46]

It is the policy of the DoD that all cost estimates for weapon systems will reflect the expected ultimate cost to acquire the system. All cost estimates should reflect the best estimate of the amounts ultimately to be paid

specifically incorporating anticipated changes in future price levels, i.e.,inflation. DoD Instruction 7041.3 gives the following guidelines for the treatment of inflation:

1) To assure consistency in comparative studies, all estimates of costs and financial benefits for each year of the planning period will first be made in terms of constant dollars; that is,in terms of the general purchasing power of the dollar at the time of decision.

2) When inflation is considered important to the conclusion of the study, a second computation will be made in terms of current(inflated) dollars. Using the constant dollar estimates as a baseline, inflation should then be included, by using the Office of the Assistant Secretary of Defense price indices for procurement.

The inflated value of any future expenditure can be obtained by multiplying that cost by the applicable price level index. When both discounting and inflation are performed, DoD Instruction 7041.3 suggests that the costs be first inflated, and then discounted. [Ref. 13: p. 48]

3. The learning curve

One of the assumptions needed to perform life cycle costing is production quantity. Sometimes the cost data collected on unit production costs do not correspond exactly to the production quantity to be used for life cycle costing analysis. The learning curve allows the cost analyst to convert the collected data to the production cost needed for the analysis.

The learning curve is based on historical evidence that as the total quantity of units produced increases, the man hours or costs to produce that quantity will be reduced by some constant percentage. [Ref. 13: p. 50]

Some of the factors contributing to this decline are:

a. Repetition causes workers to become more familiar with the job.

b. Development of more efficient tools and machines

c. Improvement in organization and management.

d. Solution of engineering production problems.

The general form of the equation for the learing curve is:

$$Y = AX^{B}$$

where,

Y = cost for unit

A = the cost to produce the first unit

X = the cumulative output

B = the slope of the learning curve

a. Cumulative Average Learing Curve

When an increased production quantity results in a constant percentage decline in the average cost, the cumulative average learning curve is described by, [Ref. 32: p. 18]

$$\bar{Y}_n = AX^{B}$$

where,

$\bar{Y}_n$ = cumulative average cost of n items

X = cumulative output

A = cost of the first article

B = slope of the learning curve

When the cumulative average learning curve is log-linear, the costs of individual units can be found from the relationship: [Ref. 32: p. 22].

$$Y_i = A\,(X_i^{1+B} - X_{i-1}^{1+B})$$

where,

Y_i = cost per unit for the i-th unit

X_i = cumulative unit number

A = cost of the first article

B = slope of the learning curve

b. Unit Cost Learning Curve

When an increased production quantity results in a constant percentage decline in the unit cost, the unit cost learning curve is described by the function: [Ref. 32: p. 22]

$$Y_i = AX_i^{B}$$

where,

Y_i = cost of the i-th unit

X_i = cumulative output

A = cost of the first unit

B = slope of the learning curve

When the unit cost learning curve is log-linear, the cumulative average cost can be found by the relationship: [Ref. 32: p. 22]

$$\bar{Y}_n = \left(A \sum_{i=1}^{n} X_i^{B}\right) / n$$

where,

$\bar{Y}_n$ = cumulative average cost for n items

A = cost of first unit

X = cumulative output

B = slope of the learning curve.

The production process may follow either a cumulative average or a unit log-linear curve. The relationship between the log-linear cumulative average curve and the resulting unit curve is illustrated by Figure 7.1. The relationship between the log-linear unit curve and the cumulative average curve is shown by Figure 7.2. It should be noted that the slope of the learning curve varies between different products, contractors, and even multiple production lines. [Ref. 13: p. 52]

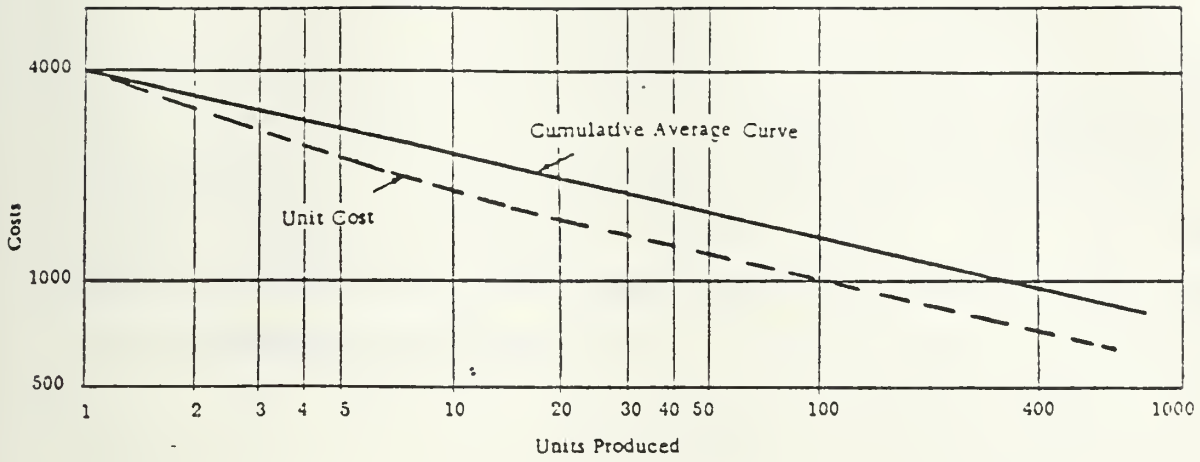


Figure 7.1 LOG-LINEAR CUMULATIVE AVERAGE CURVE.

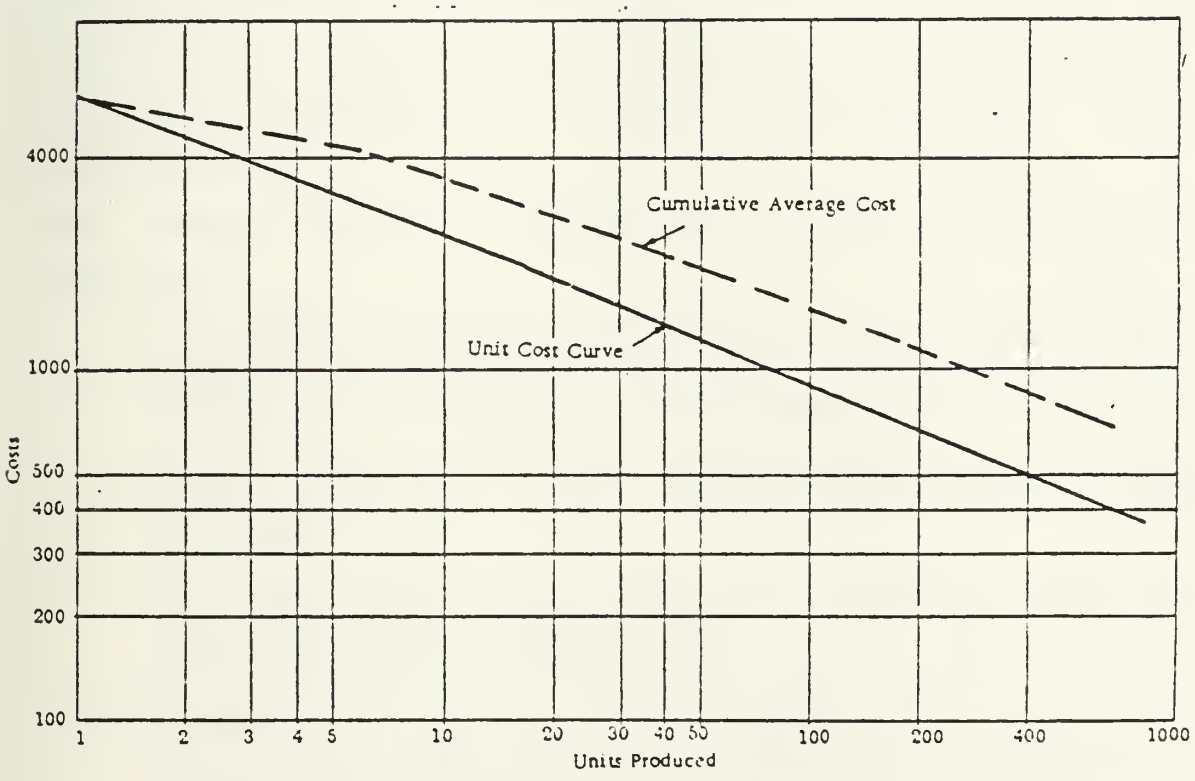


Figure 7.2 LOG-LINEAR UNIT COST CURVE.

C. Learning Curve Slope

The value of the learning curve slope, S, is defined as the ratio of Y values (either cumulative average cost or unit cost) at two X values (cumulative unit numbers) which differ by a factor of two. The slope may be expressed as: [Ref. 13: p. 57]

$$S = \bar{Y}_{2x} / \bar{Y}_{x} = A\,(2X)^{B} / A\,(X)^{B}$$

or $$S = 2^{B}$$

For an 80 percent slope, the above equation can be solved for B to yield a value of -0.322.

VIII. THE AIRCRAFT COST ESTIMATION MODEL

The objective of this chapter of the study is to review the cost estimating models that are used in the analysis for determining the life cycle costs of Naval Aircraft (F-4J, F-14A, F-18A).

A. THE RDT&E AND FLYAWAY COST-ESTIMATING MODEL

1. General description

The RDT&E and Flyaway Cost-Estiamting Model is a statistically derived model produced at the Cost Analysis Group. This is a parametric model used to estimate RDT&E and Flyaway costs of U.S. fixed-wing fighter and attack aircraft.

The development of these CERs was prompted by the need to compare the trends of resources devoted to the acquisition of tactical aircraft by the U.S. and USSR over a twenty-year period. The nature of the problem required emphasis on comparability, rather than on accuracy, of the estimates.

The ground rules and constraints of this model are as follows:

a) The CERs represent the cost to the U.S. Government of the initial series of aircraft; usually the A and B series. Factors were developed to account for the costs of follow-on series and major modifications, but they are not subjects of this presentation.

b) Unlike most aircraft CERs that generate estimates by major subsystem, in the interest of accuracy, these CERs are based on, and represent, the costs of whole aircraft.

c) Both the RDT&E and Flyaway cost data bases from which the CERs were derived comprise mixes of fighter and attack aircraft. These CERs, then, can be used to estimate costs of either type.

d) Included in each of the preferred CERs is a time-sensitive term intended to explicity highlight the increase in cost from one generation of aircraft to the next. This is the increment in cost, it is commonly believed, that reflects the incorporation of progressively advanced technology.

2. Data Bases

As shown in Figure 8.1, the RDT&E data base includes seven Navy and Air Force fighter and attack aircraft with Initial Operational Capability (IOC) dates from 1967 to 1982. The Flyaway cost data base includes data on 13 aircraft with IOCs ranging from 1955 to 1982. [Ref. 42: p. 4]

M/D— /S—	F-100 A/C	A-4 A/B	F-102 A	F-106 A/B	F-105 D	F-4 A/B	A-6 A	A-7 A/B	F-111 A	F-14 A/B	F-15 A	A-10 A/B	F-16 A/B	F/A-18
RDT&E								•	•	•	•	•	•	•
FLYAWAY	•	•	•	•	•	•	•	•		•	•	•	•	•
IOC (YR)	55	56	56	58	60	61	63	67 & 68	68	73	75	77	80	82

Figure 8.1 DATA BASES.

3. The RDT&E Cost-Estimating Relationships

The RDT&E are those costs associated with the research, development, test, and evaluation of system hardware and software. More specifically, it includes the cost for feasibility studies; simulation or modeling; engineering design, development, fabrication, assembly and test of prototype hardware; initial system evaluation; associated documentation; and test of software.

The Cost-Estimating Relationship for the RDT&E is : [Ref. 42: p. 10]

$$RDT\&E = (1.7)(10^{-6})(W^{2.0493})(R_t^{1.7005})(1.0239^{T})$$

(Millions of FY 1981 TOA dollars)

where, W = DCPR weight. LBS.

R_t = MAX. Thrust @ S.L., LBS. + W

T = IOC Year - 1978 (Base year)

4. The Flyaway Cost-Estimating Relationships

The Flyaway costs are those costs associated with producing the aircraft, initial support equipment, training, technical and management data, initial spares and repair parts, plus many other items required to introduce a new system to the field.

The Cost-Estimating Relationship for the Flyaway cost is : [Ref. 42: p. 12]

$$CAC_{100} = (90.8)(10^{6})(W^{1.2787})(R^{0.6664})(1.011^{T})$$

(Millions of FY 1981 TOA dollars)

where, W = DCPR weight. LBS.

R = MAX. Thrust @ S.L., LBS. + TOGW, LBS.

T = IOC YEAR - 1978 (Base year)

CAC_{100} = Estimated Cumulative Average Cost at 100th unit.

B. NAVAL AIRCRAFT OPERATING AND SUPPORT COST-ESTIMATING MODEL.

1. General Description

Naval Aircraft Operating and Support Cost-Estimating Model is a statistically derived model produced at the Administrative Science Corporation. This is a paramatric model used to estimate Naval aircraft operating (O&S) costs. The purpose of this model is to use as a training aid for OP-96D aircraft cost analysts, as well as a model capable of generating O&S estimates for Naval aircraft.

2. Cost-Estimating Relationships

This section contains a definition of each cost element, cost-estimating relationship(CER). Costs are based on FY 79 data and therefore are in real FY79 dollars. Each parametric CER is described by t-statistics (shown in parentheses under the appropriate coefficients), adjusted

TABLE II

OPERATING AND SUPPORT COST ELEMENTS

Unit Mission Personnel
1. Aircrew
2. Maintenance Personnel
3. Other unit Personnel

Unit Level Consumption
4. Petroleum, Oil Lubrications
5. Maintenance Material
6. Personnel Support Supplies
7. Training Ordnance

Depot Level Maintenance
8. Airframe Rework
9. Engine rework
10. Component Rework
11. Other Depot Support
12. Installation of modifications
Depot cost of modification
Installation

Sustaining Investments
13. Replenishment Spares
14. Replacement Support Equipment
15. Modifications Procurement

Installation Support Personnel
16. Base operating Support Personnel
17. Health careSupport Personnel

Indirect Personnel Support
18. Base Operating Support
19. Health care Support
20. Permanent Change of Station
21. Temporary Aditional Duty

Depot Non-Maintenance
22. General Depot Support
23. Second Destination Transportation
24. Other Support

Personnel Acqusition and Training
25. Personnel Acqusition
26. Personnel Training
27. Transient/ Holding Account

coefficients of determination (R^2), the sample size (N), the F-statistic (F), and the standard error of the estimate(S.E.E.).

All CER's definitions are for the cost of a single operating aircraft or unit of equipment (UE) operated in a squadron. To obtain the squadron cost or force cost, the

analyst simply has to multiply the cost for UE by the number of operating aircraft. The O&S cost elements are in Table II. [Ref. 43: pp. 6-7]

1. Aircrew

This is the cost of pay for personnel, both officer and enlisted, who operate the squadron aircraft. Computing the number of aircrew members in the squadron is usually done by using two components. The first component is the crew size. The second factor is the crew factor which is simply the number of crews per aircraft. It can also be described as the total number of aircraft in the squadron. Accordingly the total number of aircrew members is obtained by multiplying the crew size times the crew factor. The equation for the annual aircrew cost per aircraft is :

$$A = OA + EA$$

$$OA = O \times CF \times OPR$$

$$EA = E \times CF \times EPR$$

where, A = the cost per aircraft of paying the aircrew members

OA = the cost per aircraft of paying officer aircrew members

EA = the cost per aircraft of paying enlisted aircrew members

O = the number of officers per aircrew

CF = the crew factor or the number of aircrews contained in the squadron divided by the number of operating aircraft

OPR = the officer pay rate

E = the number of enlisted personnel per aircrew

EPR = the enlisted pay rate

2. Maintenance Personnel

This element consists of all the manpower necessary to provide the total number of preventive and corrective maintenance actions on the aircraft and its installed systems and equipments both at the organization and the intermediate levels. In terms of squadron organization, it

consists primarily of personnel in the maintenance department and in the aircraft intermediate maintenance department except for aircrew members.

Currently there is no data source which reports actual squadron manpower cost on a functional basis or by department. Approved manning by department is available from the Squadron Manning Documents(SQMD) The equation for the annual maintenance personnel is :

$$MP = (MO \times EPR) + (MOO \times OPR)$$

$$MO = 16.9620 + 0.0083\ MMHMO - 0.9356\ NA$$

$$R^2 = 0.943$$

$$N = 8$$

$$F = 59.08$$

$$S.E.E. = 1.30$$

where, MP = the cost of Maintenance Personnel necessary to support the aircraft system

MO = the number of maintenance enlisted personnel necessary to support the aircraft system

EPR = the enlisted pay rate

MOO = the number of maintenance officers necessary to support the aircraft system

OPR = the officer pay rate

MMHMO = the direct maintenance manhours per month, as defined by the 3M systems, necessary to support in 15 the weapon system

NA = the number of operating aircraft in the squadron

3. Other unit personnel

This is the cost of all other personnel in the squadron i.e., non-aircrew and non-maintenance. It consists primarily of non-aircrew in the Executive, Administration, and Operations Departments and the Integrated Services Branch. Approved manning by department is available from the squadron Manning Documents(SQMD's). The equation for the annual other unit personnel cost is :

$$OUP = (OO \times OPR) + (OUE \times EPR)$$

$$OUE = (2.7482\ OSM^{0.5483}\ / NA$$

$$OSM = ((O + E) \times CF + MO + MOO) \times NA$$

$$R^2 = 0.734$$

N = 7

F = 21.49

S.E.E. = 0.086

where, OUP = the cost of other unit personnel

OO = the number of other unit officers necessary to support the aircraft

OPR = the officer pay rate

OUE = the number of other unit enlisted personnel necessary to support the aircraft

EPR = the enlisted pay rate

OSM = the total number of other squadron manpower which is to be supported by the other unit enlisted personnel

NA = the number of operating aircraft in the squadron

O = the number officers per aircrew

E = the number of enlisted personnel per aircrew (from Element 1)

CF = the aircrew factor, or the number of aircrews contained in the squadron divided by the number of operating aircraft (from Element 1)

MO = the number of maintenance and operating enlisted personnel necessary to the support the aircraft system (from Element 2)

MOO = the number of maintenance officers necessary to support the aircraft system (from Element 2)

4. Aviation, Petroleum, Oil and Lubricants

Aviation POL is the cost of petroleum, oil and lubricants (including fuel additives) consumed by squadron aircraft in flight operations and maintenance. The equation for the annual POL cost per aircraft :

POL = (PG x POLF x FHY) / 1,000

$POLF = 1.0253\ MS^{0.6350}\ GTOW^{0.6636} PD^{0.4973}$

$R^2 = 0.855$

N = 21

F = 41.32

S.E.E. = 0.23

where, POL = the annual cost of aviation petroleum, oil and lubricants

PG = the price per gallon for aviation POL

POLF = the number of gallons per hour consumed by the aircraft

FHY = the number of flying hours per aircraft per year

MS = the maximum speed for level flight at altitude (knots)

GTOW = the gross take-off weight of the aircraft (thousands of pounds)

PD = a propellar dummy such that
ln PD = 1 if the aircraft is propellar driven
ln PD = 0, otherwise

5. Maintenance material

This is the cost of all consumable maintenance supplies whether acquired by the department stock fund or any other method of funded purchase. The costs are incurred at both the organizational and the intermediate levels The equation for the annual maintenance material cost per aircraft is :

$MMC = (MM \times FHY) / 1,000$

$MM = 2.6108\ MMHFH^{0.8576} \times MS^{0.1981}$

$R^2 = 0.829$

$N = 19$

$F = 44.20$

S.E.E. = 0.17

where, MMC = the annual cost of maintenance material

MM = the cost per flying hour of maintenance marterial

FHY = the number of flying hours per aircraft per year

MS = the maximum speed for level flight at altitude (knots)

MMHFH = the number of direct maintenance manhours per flying hour as defined by the 3M system

6. Personnel Support Supplies

This is the cost of all non-maintenance items used by the squadron for aircraft operations. It relates primarily to the health, safety and welfare of the aircrew. The equation for the annual personnel support supply costs is :

$PSS = (PS \times FHY) / 1,000$

$PS = 9.1549 + 0.5182\ (O + E) + 32.0680\ RD$

$R^2 = 0.93$

$N = 21$

F = 139.84

S.E.E. = 2.54

where, PSS = the annual cost of personnel support supplies

PS = the cost per flying hour of personnel support supplies

FHY = the number of flying hours per aircraft per year

O = the number of officers per crew

E = the number of enlisted personnel per aircrew

RD = a reconnaissance dummy such that RD = 1 if the aircraft is a reconnaissance aircraft, RD = 0 , otherwise

7. Training Ordnance

This is the cost of all conventional expendables used in non-combat flight operations of squadron aircraft for the purpose of keeping aircrews proficient in weapons delivery techniques. It includes the cost of sonobuoys, pyrotechnic, ballistic and guided weapons as well as all conventional ordnance.

No cost-estimating relationship is given since training ordnance costs are not related to the physical characteristics or reliability and maintainability parameters which have been used throughout the model. The analyst can refer to the Table III which provides estimated costs of training ordnance requirements per crew for most carrier aircraft. [Ref. 43: p. 28]

TABLE III

ANNUAL ESTIMATED COSTS OF TRAINING REQUIREMENTS PER CREW

(FY79$k)

F-14J	43.4
F-14A	50.9
A-6E	132.6
A-7E	77.9

8. Airframe Rework

Airframe rework costs are the cost, including labor, material and overhead, of making periodic inspections, repairs and overhaul of the airframe to insure its material condition. Because of the long lead times involved between rework for specific aircraft and because of the variability of the data the equation used in this model is now based on a three year average of aircraft rework data.

$AR = (UAR \times 12) / I$

$UAR = 0.811\ MMHFH^{0.6934} \times MS^{0.2646} \times EW^{0.4610}$

$R^2 = 0.732$

$N = 19$

$F = 17.39$

$S.E.E. = 0.28$

where, AR = the annualized cost of an airframe rework

UAR = the airframe rework interval in months

I = the airframe rework interval in months

MMHFH = the number of direct maintenance manhours per flying hour as defined by the 3M system

MS = the maximum speed for level flight at altitude (knots)

EW = the empty weight of the aircraft (in thousands of pounds)

9. Engine Rework

This is the cost of repairing and overhauling aircraft engines at the air rework facilities or similar facilities of other services or contractors. The equations given below represent two different approaches to estimating engine costs. The first approach is based simply on estimating the engine maintenance cost per engine hour, while the second one is broken down into the primary components that will exist when the new maintenance philosophy is fully implemented, i.e., the depot arrival rate of the engines and the cost to repair those engines. The equations were obtained to estimate both of these parameters.

$$ERT = (ERH \times EN \times FHY) / 1{,}000$$

$$ERH = 1.2791\ TH^{1.4577} \times FD^{0.5022} \times MED^{0.3649}$$

$R^2 = 0.96$

$N = 9$

$F = 121.98$

$S.E.E. = 0.09$

where, ERT = the total cost of engine rework

ERH = the cost per hour per for depot maintenance

EN = the number of engines mounted on the aircraft

FHY = the number of flying hours per aircraft per year

TH = the engine thrust in thousands of pounds

FD = a dummy variable such that
ln FD =1 if the engine is a turbo fan engine
ln FD = 0, otherwise

MED = a dummy variable such that ;
ln MED = 1 if these is more than one engine mounted on the aircraft. ln MED = 0, otherwise.

Alternative equation is ;

$$ERT = (ERM/DAR) \times EN \times FHY$$

$$ERM = 4.2685\ FD^{0.2396} \times TH^{0.7497}$$

$R^2 = 0.89$

$N = 10$

$F = 37.14$

$S.E.E. = 0.16$

$$DAR = 5837.9209\ TH^{-0.94824} \times MED^{0.2783}$$

$R^2 = 0.72$

$N = 14$

$F = 22.50$

$S.E.E. = 0.29$

where, ERT = the total cost of engine rework

ERM = the unit cost of repairing an engine at the depot

DAR = the depot arrival rate in operating hours, i.e., the total hours accumulated by the engines divided by the number of engines requiring depot repair

EN = the number of engines mounted on the aircraft

FHY = the number of flying hours per aircraft per year

TH = the engine thrust in thousands of pounds

FD = a dummy variable such that
ln FD = 1 if the engine is turbofan engine
ln FD = 0, otherwise

10. Component Rework

This is the cost of reworking or repairing components of the aircraft and its associated support equipment. This maintenance, which generally involves greater technical capability and more extensive facilities than are available at base level, is usually performed at the air rework facilities but can also be done by other service or by a contractor. The formula for the annual component rework cost is :

$$CR = (CRF \times FHY) / 1{,}000$$

$$CRF = 3.4909\ MMHFH^{0.7347}\ EW^{0.5817}$$

$R^2 = 0.88$

$N = 9$

$F = 49.90$

$S.E.E. = 0.16$

where, CR = the annual cost of component rework

CRF = the cost per flying hour of component rework

FHY = the number of flying hours per aircraft per year

MMHFH = the number of direct maintenance manhours per flying hours as defined by the 3M system

EW = the empty weight of the aircraft (thousands of pounds)

11. Other depot Support

Other depot support is the cost of personnel, material and contractual support incurred at the centralized depot facilities in order to support fleet aircraft. Sub-programs include preservation, salvage, fleet training, customer services, and other support manufacturing.

The equation for the annual other depot support cost is :

ODSC = (ODS x FHY) / 1,000

ODS = -2.4770 + 0.0452 MS + 0.0341 AEC

R^2 = 0.83

N = 15

F = 34.40

S.E.E. = 10.26

where, ODSC = the annual cost for other depot support

ODS = the cost per flying hour for other depot support

FHY = the number of flying hours per aircraft per year

MS = the maximum speed for level flight at altitude (knots)

AEC = the cost per flying hour of the total of the remaining depot support costs consisting of component rework and airframe rework

AEC = (CR + ERT + AR) / FHY

12. Installation of Modifications

This is the cost of installing modification material to aircraft ground support equipment, and training equipment to enable that equipment to perform mission essential tasks(not new capability), and to improve safety, reliability or reduce maintenance costs.

There are a number of factors that make this element particularly difficult to handle for the cost analyst. The first factor which complicated the estimation of modification

installation costs is that they are by nature not dependent upon parameters which are predictable or easily treatable on an analytical basis. The second factor is simply that there is a lag involved in the time that modifications are procured and the time in which they are installed. This is a result of the lead time of the procurement, funding problems and scheduling of the installation.

Despite several problems previously mentioned, it does appear that installation costs comprise a rather steady, ten percent of procurement costs in total. Therefore, perhaps the best way to estimate modification installation costs would be as the percent of modification procurement costs.

$$MI = 0.1\ MP$$

where, MI = the cost of installation of safety/reliability modifications

MP = the cost of the procurement of safety /reliability modifications

13. Replenishment Spares

This is the of procuring aircraft assemblies, spare and repair parts which are nomally repaired and returned to stock. It arises because of the demand for repairable items generated by attrition and various stock initiatives. This cost does not include the cost of Follow-on Out-fitting which in previous years was funded by Initial Spares procurement, but is now included with Replenishment spares The formula for the annual replenishment spares cost is :

$$RS = (RSF \times FHY) / 1{,}000$$

$$RSF = 0.4876\ UMMHFH^{1.1931} \times MS^{0.3517}$$

$$R^2 = 0.71$$

$$N = 16$$

$$F = 25.98$$

$$S.E.E. = 0.33$$

where, RS = the annual cost of procuring APN 6 replenishment spares(replenishment only) to support the aircraft system

RSF = the cost per flying hour of production APN 6 replenishment spares(replenishment only)

to support the aircraft system

FHY = the flying hours per year

UMMHFH = the number of unscheduled direct maintenance manhours per flying hours as defined by the 3M system

MS = the maximum speed for level flight at altitude given in knots

14. Replacement ground support equipment

This is the cost of replacement of ground servicing equipment, maintenance and repair shop equipment, instrument and laboratory test equipment, and other miscellaneous items, such as ground generators, jet engine test stands, test sets for radios, radars, and fire control systems, hand tools, compressors and guages. These equipment demands are generated by the need to replace common and peculiar support equipment that is worn out or destroyed. This cost has been related to the flyaway cost of the aircraft.

RGSE = 0.0025 FC

where, RGSE=the annual cost of replacement ground support equipment

FC = the cumulative average flyaway cost of the first one-hundred production aircraft.

15. Modification Procurement

This is the cost of procuring modification material for aircraft ground support equipment, and training equipment to enable that equipment to perform mission essential tasks(not new capability), and to improve safety, reliability and/or reduce maintenance costs.

There are a number of factors that make this element particularly difficult to handle for the cost analyst. The first factor is that the Cost Analysis Improvement Group(CAIG) makes the distinction between modifications which are safty and/or reliability oriented and modifications which are performance and/or effectiveness oriented. The Navy does not make this distinction in any of the budgeting, planing, or management of its modification programs. Therefore, there is no supporting data which routinely provides the break into these two categories.

The VAMOSC Total Support System presumes to show only safety/reliability modification procurement costs, but that information is based on the subjective judgement of an analyst who manually goes through the detailed information of all modification costs.

The second factor which complicates the estimation of Modification Procurement costs is that they are, by nature, not dependent upon parameters which are predictable or easily treatable on an analytical basis.

Modification Procurement can be estimated by analogy using VAMOSC data or, the analyst can use the following CER which relates modification costs to the flyaway cost of the aircraft.

$$MP = 0.0041\ FC$$

where, MP = the cost(FY79$k) of installing safety/reliability modifications

FC = the cumulative average flyaway cost the first one-hundred production aircraft(FY79$k)

16. Base Operating Support Personnel

This is the cost of the personnel providing base services, such as supply, maintenance, security, maintenance of real property and other similar functions.

Included in this element are those personnel who are assigned to the base(not the squadron) and work in the laundry, mess, supply room, and other areas. It also includes the base personnel who are permanently assigned to the AIMD of the air station.

Since it is often difficult to determine the impacts on base operating support cost of the addition or deletion of force unit such as an aircraft or squadron, the methodology used in the Navy Resource Model(NARM) program factors manual was adapted to provide an estimate for the base operating support personnel cost as well as several other elements which are similar in nature.

The computation for base operating support personnel using NARM factors is as follows:

BO = 0.0014 x TDP

BE = 0.0169 x TDP

BOP = (BO x OPR) + (BE x EPR)

where, BO = the number of base operating officers necessary to provide support to the aircraft system.

TDP = the number of total direct personnel (officers and enlisted) involved in the operating and supporting of the aircraft system. This is the sum of personnel identified in element 1-Aircrew; Element 2-Maintenance personnel; and Element 3-Other unit personnel

BE = the number of base operating enlisted personnel required to support the aircraft system

BOP = the total cost of base operating support personnel

OPR = the officers pay rate(FY79$k=24.86)

EPR = the enlisted pay rate(FY79$k=10.68)

17. Health Care Support Personnel

Health Care Support Personnel is the cost of medical personnel needed to provide medical support to the aircraft unit personnel as well as the required base support personnel(identified in Element 16-Base Operating Suppoort Personnel)

HO = 0.0038 DBT

HE = 0.0059 DBT

HCP = (HO x OPR) + (HE X EPR)

where, H = the number of health care officers necessary to support the weapon system

DBT = the total number of personnel, direct (Element 1,2 and 3) plus base operating support (Element 16), required to operate and provide base support to the aircraft system

HE = the number of health care enlisted personnel

HCP = the total cost of health care support personnel (FY79$k)

OPR = the officer pay rate(FY79$k = 24.86)

EPR = the enlisted pay rate(FY79$k=10.68)

18. Base Operating Support

This is the cost of O&MN funds necessary to provide the base services associated with the base operating support activities defined in Element 16-Base Operating Suport Personnel.

BOS = 0.4568 TDP

where, BOS = the O&MN funds necessary to provide base operating support to the aircraft system(FY79$k)

TDP = the number of total direct personnel officers and enlisted involved in the operating and supporting of the aircraft system.

This is the sum of personnel identified in Element 1-Aircrew; Element 2-maintenance personnel; Element 3-Other unit personnel

19. Health Care Support

This is the cost of medical material needed to provide medical support to aircraft unit personnel and to base personnel who provide the direct support to the aircraft. This cost is associated with the health care support personnel in Element 17

HOM = 0.1148 DBT

where, HOM = health care O&MN funds(FY79$k)

DBT = the total of personnel, direct (Element 1, 2 and 3) plus base operating(Eliment 16) support, required to operate and provide base support to the aircraft system.

20. Permanent Change of Station (PCS)

Permanent Change of Station (PCS) consists of costs of incident to the permanent change of station of squadron and base operating personnel, either individually or as an organized unit.

PCS rates are figured in the Navy Resource Model Program Factors Mannual by dividing the total PCS cost by the total number of personnel This produces an annual PCS cost per person(officer, enlisted) which can be applied to the number of people necessary to operate and support an aircraft.

The Cost-Estimating Relationship of the PCS is as follows :

PCS = 1.3680 DBO + 0.4736 DBE

where, PCS = the annual cost(MPN funds, FY79$k) of permanent change of station for weapon system direct and base operating personnel

DBO = the total number of officer personnel, direct (Eliments 1,2 and 3) plus base operating (Element 16), required to operate and provide base support to the aircraft system.

DBE = the total number of enlisted personnel, direct (Element1,2 and 3) plus operating (Element 16), required to operate and provide base support to the aircarft system.

21. Temporary Additional Duty (TAD)

Air Temporary Additional Duty (TAD) is the cost of travel lodging and incidental expenses incurred so that squadron personnel can receive training(usually maintenance related).

This cost which is usually small, is dependent on the size of the squadron, especially the maintenance department, and the complexity of the aircraft. The NARM has representative costs for TAD, but they are not particulary accurate. The VAMOSC-TSS is currently the best historical source for these costs. VAMOSC gets these data annually from the Navy Cost Information System (NCIS).

Table IV provides a representative sample of air TAD costs for FY78 and FY79 [Ref. 43: p. 62]. Estimates can be obtained by analogy by using data for current aircraft or by scaling.

22. General Depot Supply

This is the cost of manpower and material needed to perform the depot supply operations required for the support of the aircraft. When a new aircraft is introduced into the fleet, spare parts are procured to sustain operations. These parts are introduced into the supply system and resources are extended to manage, store, distribute, and package and crate the spares inventory and other common supply items

TABLE IV

REPRESENTATIVE AIR TAD COSTS FOR FY79

(then year $ in thous.)

AIRCRAFT	TAD costs per A/c	
	78	79
F-4J	2.3	0.9
F-4N	1.6	0.1
F-14A	1.1	0.3
F-5E	0.7	0.1
F-7E	1.6	0.4
P-3B	31.6	5.8
F-18a	_	-

which support aircraft. This cost is computed from the Navy Resources Model Program Factors Mannual by taking the cost contained in program element 7111N-Supply Depot Operations of the budget and allocating to force units on the basis of the direct requirements of manpower and operating funds, i.e., MPN, O&MN and APN.

The equation for estimating the cost of Depot Supply Operations is :

$$SDO = 0.0497 (ACR + ACO + RS)$$

where, SDO = the annual cost of depot supply operations required to support a weapon system(FY79$k)

ACR = the annual cost of aircraft reworks defined to be the sum of the annual cost of airframe rework (Element 8),Engine rework(Element 9),. and Component rework(Element 10)(FY79$k)

ACO = the annual cost of aircraft operations, defined to be sum of the annual cost of POL(Element 4), Maintenance Material(Element 5), and Personnel Support Supplies(Element 6)(FY79$k)

RS = the annual cost of producing APN 6 replenishment spares(replenishment only) to support the aircraft system(FY79$k)

23. Second Destination Transportation

This is the cost of shipping material needed to support the aircraft unit. Material includes:

(1) Spare and repair parts that are shipped between centralized repair depots and the aircraft units; and

(2) support items that are needed by aircraft unit personnel such as food and administrative supplies.

The equation for estimating the cost of Second Destination Transportation is :

SDT = 0.0388 x (ACR + ACO + RS)

where, SDT = the annual cost of Second Destination Transportation(FY79$k)

ACR = the annual cost of aircraft rwworks defined to be the sum of the annual cost of airframe rework(Element 8), Engine rework(Element 9), and Component rework(Element rework 10)(FY79$k)

ACO = the annual cost of aircraft operations defined to be the sum of the annual cost of POL (Element 4), Maintenance material(Element 5), and Personnel Support Supplies(Element 6)(FY79$k)

RS = the annual cost of procuring APN 6 replenishment spares(replenishment only) to support the aircraft system(FY79$k)

24. Other Support

This is the cost of all other support of the aircraft and the squadron. It consists of a number of different support line items funded at the system command level which provide support to the aircraft.

Since these activities support many weapon systems, it is advantageous to use the methodology in the Navy Resources Model Program Factors Mannual to allocate these costs to the various weapon systems. The allocation is made based on a number of different proxy variables such as the annual cost of aircraft rework, the annual cost of aircraft operations, the annual flying hours, and the annual Replenishment Spares cost ; or, some combination of all of these parameters.

The equation for estimating the cost of other support is :

TS = 0.1952 RS + 0.02112 FHY + 0.0907 ACR + 0.0018 (ACR + ACO + RS)

where, TS = the annual cost of other support(FY79$k)
RS = the annual cost of replenishment spares (Element15)(FY79$k)

FHY = the number of flying hours per aircraft per year

ACR = the annual cost of aircraft reworks defined to be the sum of the annual cost of Airframe Rework(Element 8), Engine Rework(Element 9), and Component Rework(Element 10)(FY79$k)

ACO = the annual cost of aircraft operations defined to be the sum of the annual cost of POL (Element 4),Maintenance Material (Element 5), and Personnel Support Supplies(Element 6) (FY79&k)

25. Personnel Acquisition

This is the cost of recruiting and examining activities necessary to support the squadron manpower required by the aircraft. The Navy Resources Model Program Factors Mannual computes this cost by summing two-thirds (2/3) of the cost of program element 81711N-Recruiting activities, and 81713N-Recruiting activities, and allocating these costs to the weapon systems on the basis of the enlisted personnel required.

The equation for estimating the cost of personnel acquisition is:

PAO = 0.0010 DBE

PAE = 0.0075 DBE

PAOM = 0.0613 DBE

PA = (PAO x OPR)(PAE x EPR) + (PAOM)

where, PAO = the number of recruiting and examining officer necessary to support the weapon system.

DBE = the total number of enlisted personnel, direct (Element 1, 2 and 3) plus base operating (Element 16)required to operate and provide base support to the aircraft system

PAE = the number of recruiting and examining enlisted necessary to support the weapon system

POAM = recruiting and examining O&MN funds necessary to support the weapon system(FY79$k)

PA = the total cost(FY79$k) of personnel acquisition

OPR = the officer pay rate(FY79$k=24.86)

EPR = the enlisted pay rate(FY79$k = 10.68)

26. Personnel Training

This is the cost of paying (1) personnel in training who will replace unit personnel, (2) the training staff and (3) training operating funds. It includes all training from recruit training to undergraduate pilot and navigator training as well as the operation and maintenance of trainers and simulators by the Fleet Aviation Specialized Operational Training Detatchments and the Naval Air Maintenance Training Detatchments. This element does not include any aspect of readiness training , which is costed as a separate squadron.

The equation for estimating the cost of personnel training is :

TO = 0.0001 DBE + 0.0075 DBT + 0.0632 DBO

TE= 0.1624 DBE + 0.0649 DBT + 0.0149 DBO

TOM = 0.0029 DBE + 0.2006 DBT + 0.0461 DBO

TT = (TO x OPR) + (TE x EPR) + TOM

where, TO = the number of officer staff required for training duties

DBE = the total number of enlisted personnel, direct (Element 1,2,and 3) plus base operating (Element 16) required to operate and provide base support to the aircraft system.

DBO = the total number of officer personnel, direct (Element 1,2,and 3) plus base operating (Element16) support, required to operate and provide base support to the aircraft system.

DBT = the total number of personnel, direct(Element 1,2,and 3) plus base operating(Element 16) support, required to operate and provide base support to the aircraft system

TE = the total number of enlisted personnel required for training duties.

TOM = training O&MN funds(FY79$k)

TT = the total annual cost of individual training (FY79$k)

OPR = the officer pay rate(FY79$k = 24.86)

EPR = the enlisted pay rate(FY79$k = 10.68)

27. Transients/Holding account

This cost element can be divided into two parts; Transients and the Personnel Holding Account. Transients is the cost of personnel involved in a move, such as: accession moves, separation moves, training moves, operational moves, rotational moves, and organized unit moves. The personnel holding account is the cost of manpower which are in a non-available status. This account includes (1) all patients; (2) prisoners and others confined for judicial or disciplinary reasons; and (3) those awaiting disposition back to normal status, awaiting discharge, or in the process of discharge.

The equation for estimating the cost of Transients and Personnel Holding Accounts is :

$$OTHA = 0.0611\ DBO$$

$$ETHA = 0.056\ DBE$$

$$THA = (OTHA \times OPR) + (ETHA \times EPR)$$

where, OTHA = the number of officers in the officer Transients/Holding Account category

ETHA = the number of enlisted personnel in the enlisted Transient/Holding Account category

DBO = the total number of officer personnel, direct (Element 1,2,and 3) plus base operating (Element 16) required to operate and provide base support to the aircraft system

DBE = the total number of enlisted personnel, direct (Element 1, 2, and 3) plus base operating (Element 16), required to operate and provide base support to the aircraft system.

IX. APPLICATION OF LCC FOR THE AIRCRAFT ACQUSITION IN R.O.K.

As noted in Chapter I, R.O.K. has acquired most of its major weapon systems from foreign countries. Historically, the acquisition of weapon systems within the R.O.K. has been made using the traditional approach of trade-offs between system effectiveness and minimum procurement cost, with little or no consideration being given to operating and support costs that will be encountered when the systems are deployed in the field. Therefore, in this chapter, major consideration will be given to the O&S costs.

This chapter provides an example of LCC application for the tactical fighter acqusition program which the Korea Air Force may face in these days. This example illustrates a life cycle cost analysis involving the evaluation of two alternative aircraft. The model described in Chapter VIII are used for this purpose.

A. DEFINITION OF THE PROBLEM

There is a requirement to replace an existing old tactical fighter in the Korea Air Force for the purpose of improving operational effectiveness. The existing aircraft that they will replace are F-4s. Suppose that the Korea Air Force is considering two U.S. tactical fighters (F-14A, F-18A) as alternative aircraft. As noted in Chapter I, in every year, about six percent of the GNP which accounted to one-third of the national budget, was spent on defense. One -third of the defense expenditure, was spent on equipment maintenance.

In the Korea's semi-war situation, operational readiness is a very important consideration. Therefore, a decision is needed as to type of aircraft deemed most feasible from the standpoint of performance, reliability, and life-cycle cost.

However, for the purposes of this study, analysis and evaluation will be restricted to LCC analysis in terms of logistic support.

B. ASSUMPTIONS AND DATA BASES

In addition to the model-peculiar assumptions discussed in Chapter VIII, other assumptions relevant to our application require identification. To compare the three aircraft's LCC, the following assumptions are needed.

1. Costs are based on FY86 data and therefore are in real FY86 dollars.
2. The number of aircraft operated by each tactical fighter squadron are twelve.
3. The average flying hours per month for each of the three aircraft are 26.5 hours.
4. Annual operating and support cost for each of three aircraft for useful life will be incurred in same costs.
5. The life cycle, for the purpose of this example, is 25 years. Salvage values are not considered.
6. The life cycle cost includes R.O.K's acquisition cost plus operating and support over the 25-year period of use.

Most of the available cost information and aircraft performance data has been obtained from the following sources.

* Navy Aircraft O&S Cost-Estimating Model-FY79 Revision.
* Procurement Programs (P-1), DoD Budget for FY 1986.
* U.S. Military Aircraft Cost Hand Book.
* Defense Management Journal, Vol.20, No 1, 1984
* Janes "All the World's Aircraft"

The squadron manning is based on 1976 NARM DATA and is shown in Table V.

The reliability and performance data for each of the three aircraft are shown in Table VI.

TABLE V

SQUADRON MANNING

	F-4J	F-14A	F-18A
Aircrew	O-34	O-34	O-19
Maintenance Personnel	O-2 E-186	O-5 E-205	O-3 E-145
Other	O-2 E-55	O-1 E-54	O-1 E-44
TOTAL	O-37 E-241	O-40 E-259	O-23 E-189

TABLE VI

AIRCRAFT RELIABILITY AND PERFORMANCE DATA

	F-4J	F-14A	F-18A
MTBF	0.66	0.71	1.31
Unsched. MMH Per Failure	16.5	19.2	10.1
Unsched. MMH/FH	24.9	27.1	7.72
MMH/FH	50.8	55.9	26.2
Max. speed (knots)	1,280	1,342	1,032
Empty Weight (IBs)	28,000	37,500	23,050

C. RESULTS

Table VII is a summary of the estimates for annual O&S costs of the three aircraft calculated using Cost-Estimating Model described in Chapter VIII. The calculation processes

of operating and support costs are included in Appendix A. The results were obtained from using Cost-Estimating Model in FY79 dollars, these results then were converted to FY86 dollars by dividing the FY79 dollars by DoD deflator for the O&S costs.

TABLE VII

ESTIMATED ANNUAL O&S COSTS PER AIRCRAFT

(Thousands, FY86 dollars)

COST ELEMENT	F-4J	F-14A	F-18A
Unit Mission Personnel	532.464	563.512	308.405
Unit Level Consumption	627.052	621.586	411.236
Depot Level Consumption	394.248	769.219	314.472
Sustaining Investments	156.937	447.636	80.181
Installation Support Personnel	12.746	13.702	9.722
Indirect Personnel Support	41.202	43.391	31.188
Depot Non-Maintenance	155.900	244.512	98.027
Personnel Acquisition and Training	126.298	135.316	95.111
TOTAL	2,046.346	2,838.875	1,348.339

The next phase for application is to compute LCC for each of three aircraft. Before proceeding to next phase, one major assumption is needed. This assumption is that the R.O.K. will purchase aircraft in program cost per unit incurred by U.S. Navy.

The program cost per aircraft includes average RDT&E cost per unit plus average procurement cost per unit. Actual purchase prices by FMS would be higher than program cost because actual purchase prices are decided by negotiation between two countries. For the purpose of analysis, these data were obtained from Procurement Programs(P-1) for FY1986 and U.S. Military Aircraft Cost Handbook. These Data are shown in Table VIII.

TABLE VIII

AIRCRAFT PROGRAM COST FOR FY86

(Millions, FY86 dollars)

	F-4J	F-14A	F-18A
Total Program	367.9 *	838.6	2,701.4
Production Quantities	34	18	84
Acquisition Cost per Unit	10.82	46.590	32.159

* Program cost for the F-4J were obtained by converting program cost for the FY70 to the FY 86 dollars by using DoD deflator for the procurement cost.

Referring to Table VIII the acquisition costs paid by R.O.K. for each of three aircraft are $10.82 Million for the F-4J, $46.590 Million for the F-14A, and $32.159 Million for the F-18A aircraft. These values are in FY86 dollars.

For purposes of this thesis, the average life of the individual aircraft was projected to be 25 years.

When evaluating two or more alternatives on a relative basis, the individual cost projections for each alternative must be discounted to the present value. Therefore, a 10% discount factor and a 6% inflation rate were assumed. Costs for life cycle of 25 years of each alternative are included in Appendix B.

D. ANALYSIS OF RESULTS.

For the purpose of this study, analysis and evaluation will be focused on the life cycle cost in terms of logistics support. The problem is to select the best among two alternatives on the basis of reliability and life-cycle cost because our analysis and evaluation are restricted to life cycle cost analysis in terms of logistics support.

TABLE IX

LIFE CYCLE COST ANALYSIS BREAKDOWN

(Thousands in FY86 dollars)

Cost Category	F-4J		F-14A		F-18A	
	Cost($)	% of Total	Cost($)	% of Total	Cost($)	% of Total
1. Acquisition cost	10,820	24.8	46,590	51.6	32,159	59.8
2. Operating & Support Cost						
a. Unit Mission Personnel	8,546	19.6	9,023	9.8	4,944	9.2
b. Unit Level Consumption	10,029	23	9,944	10.8	6,556	12.2
c. Depot Level Maintenance	6,322	14.5	12,335	13.4	4,977	9.3
d. Sustaining Investments	2,485	5.7	7,182	7.8	1,343	2.5
e. Installation Support Personnel	2,180	0.5	184	0.2	161	0.3
f. Indirect Personnel Support	654	1.5	644	0.7	484	0.9
g. Depot Non-Maintenance	2,529	5.8	3,959	4.3	1,558	2.9
i. Personnel Acquisition & Training	2,006	4.6	2,210	2.4	1,505	2.8
SUB-TOTAL	32,783	75.2	45,481	49.4	21,577	40.1
GRAND-TOTAL	43,633	100	92,071	100	53,736	100

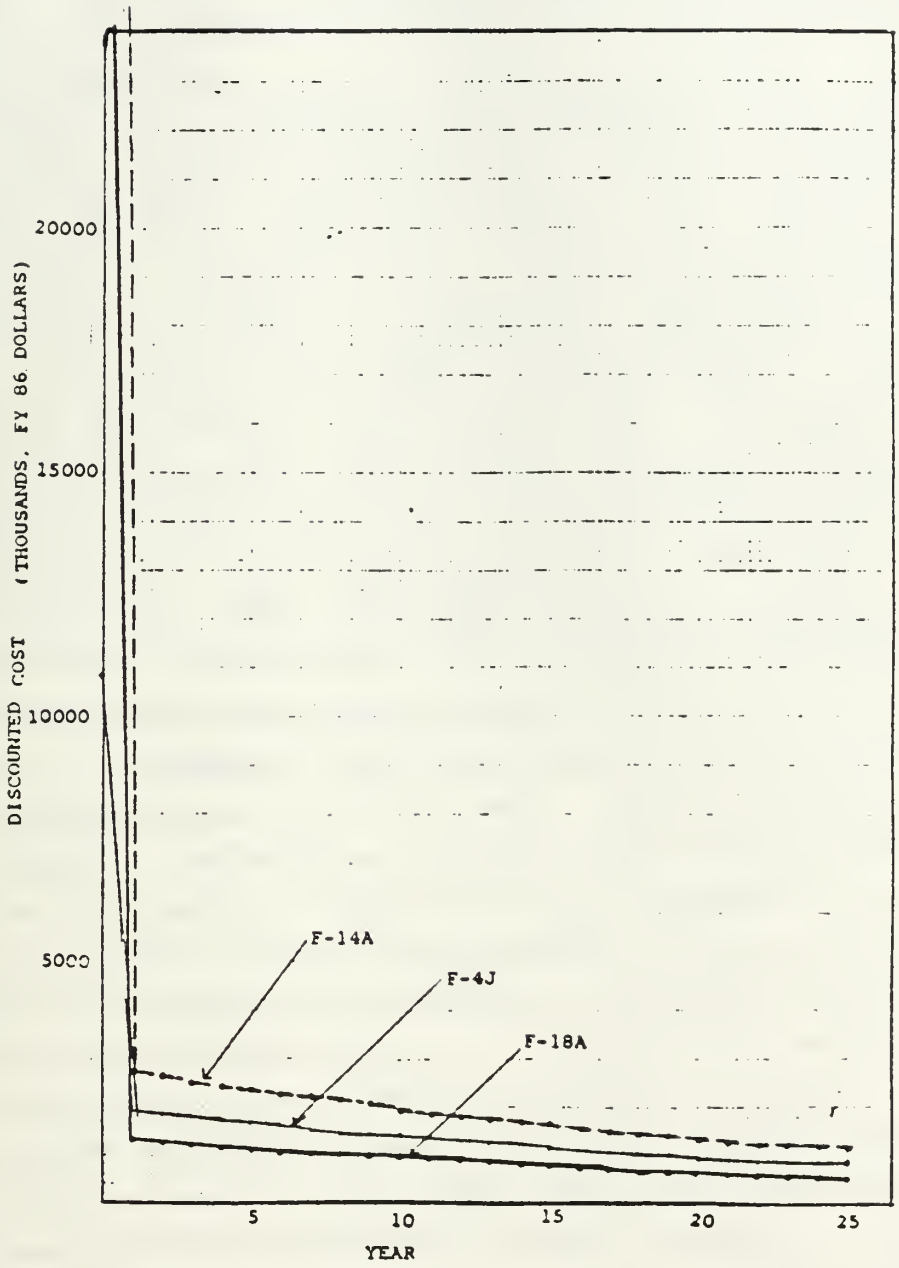


Figure 9.1 Alternative Cost Profiles (Discounted Costs).

A comparison of alternatives " F-14A " and " F-18A " using this criterion is presented in Table IX, and the cost profiles are illustrated in Figure 9.1. These values are the present values in FY86 dollars.

The results of this analysis support the "F-18A" as the preferred alternative on the basis of life cycle cost and reliability. As shown in Table IX, acquisition cost for the F-18A among two alternative aircraft is lower than the F-14A's acquisition cost. The F-18A also is far less expensive to operate and support than the F-14A and F-4J. Consequently, total LCC for the F-18A aircraft is lower than the F-14s. Operating and support costs are a significant portion of a weapon system's total life cycle cost. As showned in Table IX, estimates of two alternative aircraft and one existing aircraft O&S costs as a percentage of total life cycle cost are 49.4 percent for the F-14A, 40.1 percent for the F-18A and 75.2 percent for the F-4J aircraft. Operating and support costs constitute about half the total LCC of an aircraft weapon system. Therefore, it is important for DoD decision-makers to analyze such costs in detail when considering the acquisition of new systems.

As discussed earlier, the F-18 is less expensive to operate and support than the F-4s and F-14s. Table VII showed that the F-18 to cost only half as much to operate and support than F-14. Those costs for the F-18 also were reduced by about one-third compared with existing aircraft, F-4. From the LCC results, it is not clear to what extent reliability and maintainability improvements have affected operating and support costs as compared with the effects of technological advances and changes in complexity and capability. However, the LCC results of each aircraft showed that reliability and maintainability are important factors in determining operating and support costs. Increased reliability and maintainability in the form of

reduced maintenance personnel requirements and logistic support lead to potential savings in O&S costs. The higher the failure rates and the more equipment there is to fail, the higher the maintenance cost for parts and personnel. Similarly, the more difficult access is to components and parts, the greater will be the time required to remove and replace an item.

Referring to Table VI, reliability of the F-18 is higher than that of the F-14 weapon system. The reliability of the F-18 is superior to other aircraft (F-4J, F-14A) because of its design. The F-18 also is more maintainable than the alternative aircraft, F-14 and the existing aircraft, F-4. Table VI showed that a maintenance man-hours per flight hour of 26.2 for the F-18, compared to 50.8 for the F-4 and 55.9 for the F-14. The O&S costs of each aircraft imply that potential savings may accrue from increased reliability and maintainability in the form of reduced maintenance personnel requirements and logostics support. The personnel requirements for each aircraft are shown in Figure 9.2

The squadron manning for the F-18 was reduced by about one-third compared with the F-14, by about one-fourth compared with the F-4. Most of the reduction was to be in maintenance functions. The aircrew requirements for the F-18 are one-half those of F-14 because the F-18 is a single-seater, whereas the F-14 and F-4 are two-seaters. Therefore, personnel costs for the F-18 are lower than for the F-14 and F-4 aircraft

The extensive use of non-corrosive composite materials and fewer fastener types reduced the depot level airframe rework cost for the F-18. In addition, engine rework cost was substantially lower for the F-18 than for the F-14 and the F-4 due to fewer parts and lighter weight. For example, the F-18's engines have about 7,700 fewer parts and weigh half as much as the F-4s.

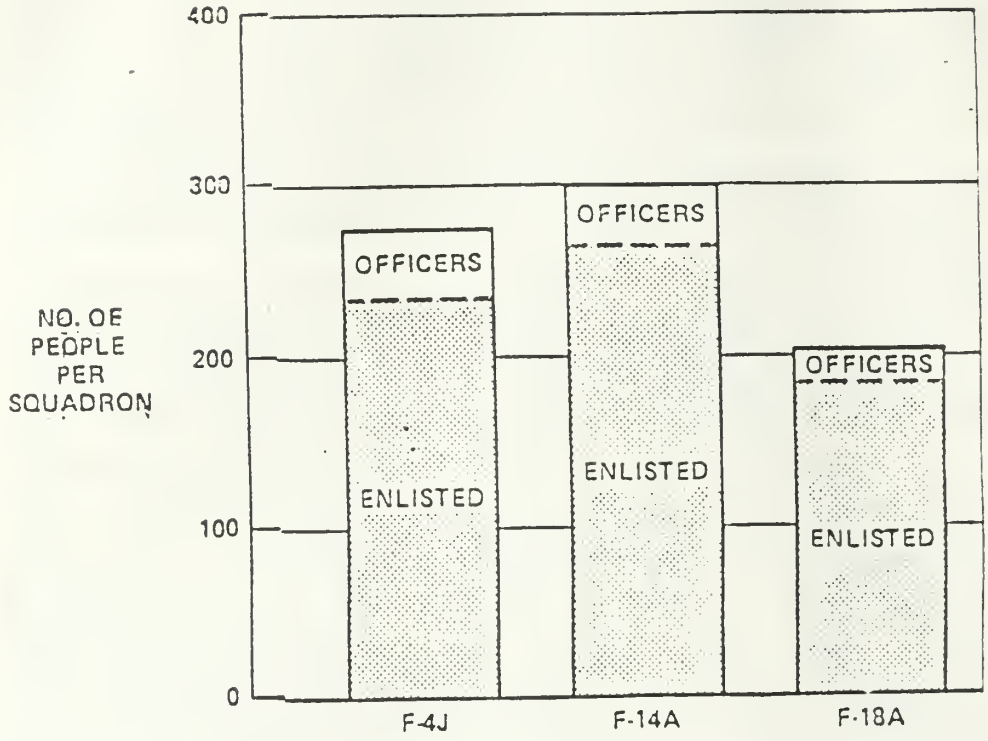


Figure 9.2 SQUADRON MANNING.

Spares costs per aircraft were estimated to be lower for the F-18 than the F-14. Navy officials attributed lower spares costs for the F-18 as compared with the F-14 to reliability and maintainability efforts. Spares costs for the F-14 are more than double those for the F-4s. Subsystem complexity may be of one of the causes for this increase. However, we suspect that less system complexity accounts for much of the difference.

These LCC results showed that reliability, maintainability and complexity of weapon systems are major factors affecting LCC, especially O&S costs over its useful life.

In conclusion, the results of this analysis support the "F-18" as the preferred alternative on the basis of life cycle cost. The F-18 aircraft is more reliable and easier to maintain than the F-14. These factors of the F-18 result in reducing significantly it's LCC, especially O&S costs.

X. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to introduce the LCC concepts within the R.O.K. military and present the LCC application methodology in new weapon systems acquisition for the R.O.K. military.

It has been shown that life cycle costing has the potential to be an excellent management tool for controlling the total life cycle costs of a system during the acquisition process. Life cycle cost also can be viewed as a useful procurement technique in which competing systems are evaluated on the total cost over their useful life rather than selection being based on initial acquisition cost.

The R.O.K. military has concentrated on R&D and production for weapon systems since 1976. However, the R.O.K. still acquires most of its sophisticated weapon systems from foreign countries. In any case, cost estimating plays an important role. The apparent fact is that the O&S costs are increasing at an alarming rate and often exceed the initial acquisition cost. The LCC results of application indicated that O&S costs constitute about half the total LCC of an aircraft weapon system. This requires that the life-cycle cost estimating methodologies must be applied as a major management tool in today's acquisition process for the Korean military. Implementation of the concept and methodologies presented in this thesis implies that some change has to be made in the procurement criteria actually in practice within the R.O.K. military in order to make operating and support costs a real factor in source selection for acquisition of weapon systems.

The LCC results also showed that reliability and maintainabilty are the most important factors in determining O&S costs. Significant savings will be achieved through

investments early in the program that will increase system reliability and simplify maintenance. Reliability and logistic supportability are design attributes, and their improvement will markedly increase system readiness. Therefore, reliability and maintainability must be emphasized in new weapon systems acquisition as key considerations.

The implementation of the life cycle cost concept and techniques by the R.O.K. military will improve considerably the decision making process in weapon systems acquisition programs. At the same time, a more rational view of future costs incurred by introduction of a new system into the organization will result in more accurate budget estimates.

Life cycle cost is not a panacea or a substitute for managerial decision making. It is concept which foster good management. By managing this concept effectively, DoD managers can reduce the upward trend of O&S costs; therefore, making more funds available to acquire new systems to meet the growing military threat.

The R.O.K. military must recognize the importance of these concepts and methodologies. Also, these concepts and methodologies must be reflected in the acquisition strategy and the logistics support management policy.

In order to implement the LCC analysis methodology during the weapon system acquisition process in R.O.K.military it is proposed that the DoD takes the following actions:

1. Training on LCC procurement policies and procedures should be conducted at Service schools
2. Cost-estimating model by using computer should be developed. In herent in the use of LCC models is the need to have accurate historical cost data on similar systems. This data does not exist. Therefore, DoD should develop a system which will collect and report O&S costs by weapon system.
3. DoD should get logisticians involved in the acquisition process, as early as concept development, and have them establish a dialogue with the program managers and contractor personnel to impress upon them the importance of support costs considerations.

APPENDIX A

CALCULATIONS FOR THE COST OF OPERATING AND SUPPORT

(FY79 DOLLARS)

A. F-4J

UNIT MISSION PERSONNEL

1. Aircrew

 A = OA + EA

 OA = O x CF x OPR

 EA = E x CF x EPR

 O = 2, CF = 34/12 = 2.83, OPR = 24.86

 OA = 2 x 2.83 x 24.86 = 140.708

 EA = 0, A = 140.708 + 0 = 140.708

2. Maintenance Personnel

 MP = (MO x EPR) + (MOO x OPR)

 MO = 15.7, EPR = 10.68, OPR = 24.86

 MP = (15.7 x 10.68) + (2/12 x 24.86) = 171.819

3. Other Unit Personnel

 OUP = (OO x OPR) + (OUE x EPR)

 OPR = 24.86, OUE = 4.58, EPR = 10.86

 OUP = (1/12 x 24.86) + (4.58 x 10.86) = 50.986

Unit mission personnel cost = 140.708 + 171.819 + 50.986
= 363.513

UNIT LEVEL CONSUMPTION

4. Petroleum, Oil Lubricants

 POL = (PG x POLF x FHY) / 1000

 POL = (0.6 x 1408 x 318) / 1000 = 268.646

5. Maintenance material

MMC = (MM x FHY) / 1,000

MM = 339, MMHFH = 50.8 MS = 1280

MMC = (339 x 318) / 1,000 = 107.802

6. Personnel Support Supplies

PSS = (PS x FHY) / 1,000

PS = 9.1549 + 0.5182 (O + E) + 32.0680 RD

PS = 9.1549 + 0.5182 (2 + 0) + 32.0680 (0) = 10.191

PSS = (10.191 x 318) / 1,000 = 3.240

7. Training Ordnance

Annual estimated costs of training requirements per crew = 43.4

Unit level consumtion = 268.646+ 107.802 + 3.240 + 43.4
= 423.088

DEPOT LEVEL MAINTENANCE

8. Airframe rework

AR = (UAR x 12) / I

UAR = 262.8 I = 42

AR = (262.8 x 12)/ 42 = 75.086

9. Engine rework

ERT = (ERH x EN x FHY) / 1,000

ERH = 57.0 EN = 2 FHY = 318

ERT = (57 x 2 x 318) / 1,000 = 36.252

10. Component rework

CR = (CRF x FHY) / 1,000

CRF = 371.4

CR = (371.4 x 318) / 1,000 = 118.105

11. Other depot support

ODSC = (ODS x FHY) / 1,000

ODS = 95

ODSC = (95 x 318) / 1,000 = 30.21

12. Installation of modifications

MI = 0.1 MP

MP = 95

MI = (0.1) (95) = 9.5

Depot level maintenance cost = 75.086 + 36.252 + 118.105
30.21 + 9.5 = 269.153

SUSTAINING INVESTMENTS

13. Replenishment spares

RS = (RSF x FHY) / 1,000

RSF = (0.4876) $UMMHFH^{1.1931}$ x $MS^{0.3517}$

UMMHFH = 24.9 MS = 1280

RSF = (0.4876) (24.9)$^{1.1931}$ x (1280)$^{0.3517}$ = 279.688

RS = (279.688 x 318) / 1,000 = 88.941

14. Replacement support Equipment

RGSE = 0.0025 FC

RGSE = 0

15. Modifications procurement

MP = 0.0041 FC

MP = 18.2

Sustaining investments cost = 88.941 + 0 + 18.2 =107.141

INSTALLATION SUPPORT PERSONNEL

16. Base operating support personnel

BO = 0.0014 x TDP

BE = 0.0169 x TDP

BOP = (BO x OPR) + (BE x EPR)

BO = 0.0014 x (278/12) = (o.0014)(23. 167) =0.0324

BE = 0.0169 x (278/12) = 0.3915

BOP = (0.0324 x 24.86) + (0.3915 x 10.86) = 0.805
+ 4.181 = 4.986

17. Health care support personnel

HO = 0.0038 DBT

HE = 0.0059 DBT

HCP = (HO x OPR) + (HE x EPR)

DBT = (23.167) + 0.0324 + 0.3915 = 23.5909

HO = 0.0038 (23.5909) = 0.0896

HE = 0.0059 (23.5909) = 0.1392

HCP = (0.0896 x 24.86) + (0.1392 x 10.68) = 2.229

1.4867 = 3.716

Installation support personnel cost = 4.986+3.716 = 8.702

INDIRECT PERSONNEL SUPPORT

18. Base operating support

BOS = 0.4568 TDP

TDP = 23.167

BOS = 0.4568 (23.167) = 10.583

19. Health care support

HOM = 0.1148 DBT

DBT = 23.167

HOM = 0.1148 (23.167) = 2.660

20. Permanent change of station

PCS = 1.3680 DBO + 0.4736 DBE

DBO = 3.0843

DBE = 20.6227

PCS = 1.3680 (3.0843) + (0.4736)(20.6227)= 13.986

21. Temporary additional duty

TAD = 0.9

Indirect personnel support cost= 10.583 + 2.660 + 13.986

+ 0.9 = 28.189

DEPOT NON-MAINTENANCE

22. General depot supply

SDO = 0.0497 (ACR + ACO + RS)

ACR = 75.086 + 36.252 + 118.105 =229.443

ACO = 268.646 + 107.802 + 3.240 = 379.688

RS = 88.941

SDO = 0.0497 (229.443 + 379.688 + 88.941) = 34.694

23. Second destination transportation

SDT = 0.0388 x (ACR + ACO + RS)

SDT = 0.0388 x (229.443 + 379.688 + 88.941) = 23.595

24. Other support

TS = 0.1952 RS + 0.02112 FHY + 0.0907 ACR + 0.0018(ACR + ACO + RS).= (0.1952)(88.941) + (0.02112)(318) +(0.0907)(229.443)+0.0018(229.443+379.688+88.941)

= 17.361 + 6.716 + 20.810 + 1.257 = 46.144

Depot non-maintenance cost = 36.694 + 23.595 + 46.144

= 106.433

PERSONNEL ACQUISITION AND TRAINING

25. Personnel acquisition

PAO = 0.0010 DBE

PAE = 0.0075 DBE

POAM = 0.0613 DBE

PA = (PAO x OPR) (PAE x EPR) + (POAM)

PAO = 0.0010 (20.623) = 0.02062

PAE = 0.0075 (20.623) = 0.15467

PAOM = 0.0613 (20.623) = 1.2642

PA = (0.02062 x 24.86) (0.15467 x 10.68) + 1.2642

= 2.125

26. Personnel training

TO = 0.0001 DBE + 0.0075 DBT + 0.0632 DBO

TE = 0.1624 DBE + 0.0649 DBT + 0.0149 DBO

TOM = 0.0029 DBE + 0.2006 DBT + 0.0461 DBO

TT = (TO x OPR) + (TE x EPR) + TOM

TO = 0.0001(20.623)+(0.0075)(23.707) 0.0632(3.084) = 0.3748

TE = 0.1624 (20.623) + 0.0649 (23.707)
+ 0.0149 (3.084) = 4.934

TOM = 0.0029 (20.623) + 0.2006 (23.707) + 0.0461
(3.084) = 4.9576

TT = (0.3748)(24.86) + (4.934 x 10.68) + 4.9576
= 66.97

27. Transients / Holding account

OTHA = 0.0611 DBO

ETHA = 0.0565 DBE

THA = (OTHA x OPR) + (ETHA x EPR)

OTHA = 0.0611 (3.084)= 0.1884

ETHA = 0.0565 (20.623) = 1.1652

THA = (0.1884 x 24.86) + (1.1652 x 10.68) = 17.128

Personnel acquisition and training =2.125+66.97+17.128
= 86.223

B. F-14A

UNIT MISSION PERSONNEL

1. Aircrew

A = OA + EA

OA = O x CF x OPR

EA = E x CF x EPR

O = 2 CF = 34/12 = 2.83 OPR = 24.86

OA = 2 x 2.83 x 24.86 = 140.708

EA = 0

A = 140.708 + 0 = 140.708

2. Maintenence Personnel

MP = (MO x EPR) + (MOO x OPR)

MO = 205/12 = 17.1

MOO = 5/12 = 0.42

EPR = 10.68 OPR = 24.86

MP = (17.1 x 10.68) + (0.42 x 24.86)

= (182.628) + (10.441) = 193.069

3. Other unit personnel

OUP = (OO x OPR) + (OUE x EPR)

OUP = (1/12 x 24.86) + (54/12 x 10.86)

= 2.063 + 48.87

= 50.933

Unit mission personnel cost = 140.708 + 193.069 + 50.933

= 384.71

UNIT LEVEL CONSUMPTION

4. Petrolium, oil lubricants

POl = (PG x POLF x FHY)/1000 =(0.6 x 1272 x 318)/1000

= 242.698

5. Maintenence material

MMC = (MM x FHY)/1000

MM = 401 FHY = 318

MMC = (401 x 318)/1000 = 127.518

6. Personnel support supplies

PSS = (PS x FHY)/1000

PS = 9.1549 + 0.5182 (O + E) + 32.0680 RD

PS = 9.1549 + 0.5182 (2 + 0)+32.0680(0) = 10.191

PSS = (10.191 x 318)/1000 = 3.241

7. Training ordnance

Annual estimated costs of training requirements per crew = 50.9

Unit level consumption = 242.698+127.518+3.214+50.9

= 424.357

DEPOT LEVEL MAINTENANCE

8. Air frame rework

AR =(UAR x 12)/I

UAR = 493.8 I = 30

AR = (493.8 x 12)/30 = 197.52

9. Engine rework

ERT = 125.9 EN = 2 FHY = 318

ERT = (125.9 x 2 x 318)/1000 = 80.072

10. Component rework

CR = (CRF x FHY)/1000 = (630.6 x 318)/1000 = 200.531

11. Other depot support

ODSC = (ODS x FHY)/1000

ODS = 100.7

ODSC = (100.7 x 318)/1000 = 32.023

12. Installation of modificationsa

MI = 0.1 MP

MP = 150

MI = (0.1)(150) = 15

Depot level maintenance cost = 197.52 + 80.072 + 200.531 + 32.023 + 15 = 525.146

SUSTAINING INVESTMENTS

13. Replenishment spares

RS = (RSF x FHY)/1000

RSF = 495.6

RS = (495.6 x 318)/1000 = 157.601

14. Replacement support equipment

RGSE = 0.0025 FC

RGSE = 0

15. Modifications procurement

MP = 0.0041 FC

MP = 148 (VAMOSC 3yr avg)

Sustaining investments cost = 157.601 + 0 + 148 = 305.601

INSTALLATION SUPPORT PERSONNEL

16. Base operating support personnel

BO = 0.0041 x TDP

BE = 0.0169 x TDP

BOP = (BO x OPR) + (BE x EPR)

BO = 0.0014 x (299/12) = 0.0014 x 24.917 = 0.0349

BE = 0.0169 x (299/12) =0.4211

BOP = (0.0349 x 24.86) + (0.4211 x 10.86)

= 0.868+ 4.497 = 5.365

17. Health care support personnel

HO = 0.0038 DBT

HE = 0.0059 DBT

HCP = (HO x OPR) + (HE x EPR)

DBT = 24.917 +0.0349 +0.4211 = 25.373

HO = 0.0038(25.373) = 0.096

HE =0.150

HCP = (0.096 x 24.86) + (0.15 x 10.68)

=2.387 +1.602 = 3.989

Installation support personnel cost

= 5.365 + 3.989 = 9.354

INDIRECT PERSONNEL SUPPORT

18. Base operating support

BOS = 0.4568 TDP

TDP = 24.917

BOS = 0.4568 (24.917) = 11.382

19. Health case support

HOM = 0.1148 DBT

DBT = 25.373

HOM = 0.1148(25.373) = 2.913

20. Permanent change of station

PCS = 1.3680 DBO + 0.4736 DBE

DBO = 3.3679

DBE = 22.0041

PCS = 1.3680(3.3679) + (0.4736)(22.0041)

= 4.607 +10.421 = 15.028

21. Temporary additional duty

TAD = 0.3

Indirect personnel support cost

= 11.382 + 2.913 + 15.028 + 0.3 = 29.623

DEPOT NON-MAINTENANCE

22. General depot support

SDO = 0.0497 (ACR + ACO + RS)

ACR = 197.52 + 80.072 + 200.531 = 478.123

ACO = 242.698 +127. 518 + 3.241 = 373.457

RS = 157.601

SDO = 0.0497 (478.123 + 373.457 + 157.601)

= 50.156

23. Second destination transportation

SDT = 0.0338 x (ACR + ACO + RS)

SDT = 0.0338 x (478.123 + 373.457 + 157.601)

= 34.110

24. Other support

TS = 0.1952 RS + 0.02112 FHY + 0.0907 ACR + 0.0018 (ACR + ACO + RS)

= 0.1952(157.601) + 0.02112(318) + 0.0907(478.123) +0.0018 (478.123 + 373.457 + 157.601)

= 30.764 + 6.716 + 43.366 + 1.817

= 82.663

Depot non-maintenance cost

= 50.156+ 34.110 + 82.663

= 166.929

PERSONNEL ACQUISITION AND TRAINING

25. Personnel acquisition

PAO = 0.0010 DBE

PAE = 0.0075 DBE

PAOM = 0.0613 DBE

PA = (PAO x OPR)(PAE x EPR) + (PAOM)

PAO = 0.0010 (22.0041) = 0.022

PAE = 0.0075(22.0041) = 0.165

PAOM = 0.0613(22.0041) = 1.349

PA = (0.022 x 24.86)(0.165 x 10.68) + (1.349)

=(0.5469)(1.7622) + 1.349 = 2.313

26. Personnel training

TO = 0.0001 DBE + 0.0075 DBT + 0.0632 DBO

TE = 0.1624 DBE + 0.0649 DBT + 0.0149 DBO

TOM = 0.0029 DBE + 0.2006 DBT + 0.0461 DBO

TT = (TO x OPR) + (TE x EPR) + TOM

TO = 0.0001(22.0041) + 0.0075(25.373) + 0.0632(3.3679)

=0.0022 + 0.1903 + 0.2169

=0.4054

TE = (0.1624)(22.0041)+0.0649(25.373)+0.0149(3.3679)

=3.5734 + 1.6467 + 0.0562

=5.2703

TOM = 0.0029(22.0041) + 0.2006(25.373)+0.00461(3.3679)

=0.0638 + 5.09 + 0.1553

= 5.309

TT = (0.4054)(24.86) + (5.2703)(10.68) + 5.309

= 10.078 + 56.287 + 5.309

= 71.674

27. Transients/Holding account

OTHA = 0.0611 DBO

ETHA = 0.0565 DBE

THA = (OTHA x OPR) + (ETHA x EPR)

OTHA = 0.0611 (3.3679) = 0.2058

ETHA = 0.0565(22.0041) = 1.2432

THA = (0.2058 x 24.86) + (1.2432 x 10.68)

= 5.116 + 13.277 = 18.393

Personnel acquisition and training

= 2.313 + 71.674 + 18.393 = 92.380

C. F-18A

UNIT MISSION PERSONNEL

1. Aircrew

A = OA + EA

OA = O x CF x OPR

EA = E x CF x EPR

O = 1 CF = 19/12 = 1.58 OPR = 24.86

OA = 1 x 1.58 x 24.86= 39.279

A = 39.279 + 0 = 39.279

2. Maintenance personnel

MP =(MO x EPR) + (MOO x OPR)

MO = 16.9620 + 0.0083 MMHMO - 0.9356 NA

MMHMO = MMH / FH x FH / MO = 26.2 x 26.5 = 694.3

NA = 12

MO = 16.9620 + 0.0083 (694.3) - (0.9356) (12) =
16.9620 + 5.7627 - 11.2272 = 129.008

3. Other unit personnel

OUP = (OO x OPR) + (OUE x EPR)

OUE = (2.7482 $OSM^{0.5483}$) / 12

OSM = ((- O+E) x CF + MO + MOO) x NA

OSM = ((1+0) x 1.58 + 11.4975 + 3/12) x 12 = 159.93

OUE = (2.7482 (159.93)$^{0.5483}$) / 12 = 3.7007

OUP = (1/12 x 24.86) + (3.7007 x 10.86) = 42.261

Unit mission personnel cost = 39.279 +129.008 + 42.261
= 210.548

UNIT LEVEL CONSUMTION

4. Petroleum, oil lubricants

$POL = (PG \times POLF \times FHY) / 1{,}000$

$POLF = 1.0253\ MS^{0.6350}\ GTOW^{0.6636}\ PD^{-0.4973}$

$MS = 1006 \quad GTOW = 33.6 \quad PD = 0$

$POLF = 1.0253\ (1006)^{0.6350}\ (33.6)^{0.6636}\ (0)^{-0.4973}$

$= (82.6991)\ (10.301) = 851.882$

$POL = ((0.6) \times (851.882) \times 318) / 1{,}000 = 162.539$

5. Maintenance material

$MMC = (MM \times FHY) / 1{,}000$

$MM = 2.6108\ MMHFH^{0.8576} \times MS^{0.1981}$

$MMHFH = 26.2 \quad MS = 1006$

$MM = (2.6108)\ (26.2)^{0.8576} \times (1006)^{0.1981} = 169$

$MMC = (169 \times 415) / 1{,}000 = 70.135$

6. Personnel support supplies

$PSS = (PS \times FHY) / 1{,}000$

$PS = 9.1549 + 0.5182\ (O+E) + 32.0680\ RD$

$PS = 9.1549 + 0.5182\ (1+0) + 32.0680\ (0) = 9.6731$

$PSS = (9.6731 \times 318) / 1{,}000 = 3.076$

7. Training ordnance

Annual estimated costs of training requirements per crew = 45

Unit level consumtion = 162.539 + 70.135 +3.076 + 45

= 280.75

DEPOT LEVEL MAINTENANCE

8. Airframe rework

$AR = (UAR \times 12) / I$

$UAR = 0.811\ MMHFH^{0.6934} \times MS^{0.2646} \times EW^{0.4610}$

$MMHFH = 26.2 \quad MS = 1006 \quad EW = 22.8$

$UAR = 0.811 (26.2)^{0.6934} \times (1006)^{0.2646} \times (22.8)^{0.4610}$

$= (7.8077)(6.2299)(4.2268) = 205.595$

$AR = ((205.595) (12)) / 42 = 58.741$

9. Engine rework

$ERT = (ERH \times EN \times FHY) / 1,000$

$ERH = 1.2791\ TH^{1.4577} \times FD^{0.5022} \times MED^{0.3649}$

$TH = 16 \quad FD = 1 \quad MED = 1 \quad EN = 2$

$ERH = (1.2791)(16)^{1.4577} \times (1)^{0.5022} \times (1)^{0.3649} = 72.803$

$ERT = (72.803 \times 2 \times 318) / 1,000 = 46.303$

10. Component rework

$CR = (CRF \times FHY) / 1,000$

$CRF = 3.4909\ MMHFH^{0.7347} \times EW^{0.5817}$

$MMHFH = 26.2 \quad EW = 22.8$

$CRF = 3.4909 (26.2)^{0.7347} \times (22.8)^{0.5817}$

$= (38.456) (6.1647) = 237.069$

$CR = (237.069 \times 318) / 1,000 = 75.389$

11. Other depot support

$ODSC = (ODS \times FHY) / 1,000$

$ODS = -2.4770 + 0.0452\ MS + 0.0341\ AEC$

$AEC = (CR + ERT + AR) / FHY$

$AEC = (75.389 + 46.303 + 58.741) / 318 = 0.567 = \$567$

$ODS = -2.4770 + 0.0452 (1032) + 0.0341(567) = 60.56$

$ODSC = (60.56 \times 318) / 1,000 = 19.257$

12. Installation of modification

$MI = 0.1\ MP$

$MP = 150$

$MI = (0.1) (150) = 15$

Depot level maintenance cost= 58.741 + 46.303 + 75.389
+ 19.257 + 15 = 214.69

SUSTAINING INVESTMENTS

13. Replenishment spares

RS = (RSF x FHY)/ 1,000

RSF = 0.4876 $UMMHFH^{1.1931}$ x $MS^{0.3517}$

UMMHFH = 7.72 MS = 1032

RSF = 0.4876 (7.72)^{1,1931} x (1032)^{0,3517} = 93.52

RS = (93.52 x 318) / 1,000 = 29.739

14. Replacement support equipment

RGSE = 0.0025 FC

RGSE = 0

15. Modifications procurement

MP = 0.0041 FC

MP = 25

Sustaining investments = 29.739 +0 +25 = 54.739

INSTALLATION SUPPORT PERSONNEL

16. Base operating support personnel

BO = 0.0014 x TDP

BE = 0.0169 x TDP

BOP = (BO x OPR) + (BE x EPR)

BO = 0.0014 x (212/12) = (0.0014) (17.667) = 0.2986

BOP = (0.0247 x 24.86) + (0.2986 x 10.68)

= 0.614 + 3.189 = 3.803

17. Health care support personnel

HO = 0.0038 DBT

HE = 0.0059 DBT

HCP = (HO x OPR) + (HE x EPR)

DBT = (17.667) + (0.0247) + (0.2986) = 17.9903

HO = 0.0038 (17.9903) = 0.1061

HCP = (0.0684 x 24.86) + (0.1061 x 10.86)

= 1.7004 + 1.1331 = 2.834

Installation support personnel cost= 3.803 + 2.834

= 6.637

INDIRECT PERSONNEL SUPPORT

18. Base operating support

BOS = 0.4568 TDP

TDP = 212/12 = 17.667

BOS = 0.4568 (17.667) = 8.070

19. Health care support

HOM = 0.1148 DBT

DBT = 17.667 + 0.0247 + 0.2986 = 17.9903

HOM = 0.1148 (17.9903) = 2.065

20. Permanent change of station

PCS = 1.3680 DBO + 0.4736 DBE

DBO = 23/12 + 0.0247 = 1.9167 + 0.0247 =1.9414

DBE = 189/12 + 0.2986 = 15.75 + 0.2986 = 16.0486

PCS = 1.3680 (1.9414) + 0.4736 (16.0486)

= 2.656 + 7.601 = 10.257

21. Temporary additional duty

TAD = 0.9

Indirect personnel support cost = 8.070 + 2.065 + 10.257 + 0.9 = 21.292

DEPOT NON-MAINTENANCE

22. General depot supply

SDO = 0.0497 (ACR + ACO + RS)

ACR = 58.741 + 46.303 + 75.389 = 180.433

ACO = 162.539 + 70.135 + 3.076 = 235.75

RS = 29.739

SDO = 0.0487 (180.433 + 235.75 + 29.739) = 22.162

23. Second destination trasportation

SDT = 0.0388 x (ACR + ACO + RS)

= 0.0388 x (180.433 + 235.75 + 29.739)= 15.072

24. Other support

TS = 0.1952 RS + 0.02112 FHY + 0.0907 ACR + 0.0018
(ACR + ACO + RS)

TS = 0.1952 (29.739) + 0.02112(318) + 0.0907(180.433)
+ 0.0018(180.433+235.75+29.739)=5.805+6.716+16.365
+ 0.803 = 29.689

Depot non-maintenance cost = 22.162 + 15.072 + 29.689
= 66.923

25. Personnel acqusition

PAO = 0.0010 DBE

PAE = 0.0075 DBE·

PAOM = 0.0613 DBE

PA = (PAO x OPR) (PAE x EPR) + (PAOM)

PAO = 0.0010 (189/12 + 0.2986)
= 0.0010(15.75 + 0.2986)= 0.0010(16.0486) = 0.016

PAE = 0.0075 (16.0486) = 0.12036

PAOM = 0.0613 (16.0486) = 0.98378

PA = (0.016 x 24.86)(0.12036 x 10.68) + 0.98378
= (0.39776)(1.2854)+0.98378 =0.5113+0.9838 = 1.495

26. Personnel training

TO = 0.0001 DBE + 0.0075 DBT + 0.0632 DBO

TE = 0.1624 DBE + 0.0649 DBT + 0.0149 DBO

TOM = 0.0029 DBE + 0.2006 DBT + 0.0461 DBO

TT = (TO x OPR) + (TE x EPR) + TOM

TO = 0.0001(16.0486) + 0.0075(17.9903) + 0.0632
(1.9414) = 0.0016 + 0.1349 + 0.1227 = 0.2592

TE = 0.1624(16.0486) + 0.0075 (17.9903) + 0.0149
(1.9414) = 2.6063 + 1.1678 + 0.0289 = 3.803

TOM = 0.0029(16.0486) + 0.2006(17.9903) + 0.0461
(1.9414) = 0.0465 + 3.6089 + 0.0895 = 3.7449

TT = (0.2592 x 24.86) + (3.803 x 10.86) + 3.7449
= 6.444 + 40.616 + 3.7449 = 50.805

27. Transients/Holding account

OTHA = 0.0611 DBO

ETHA = 0.0565 DBE

THA = (OTHA x OPR) + (ETHA x EPR)

OTHA = 0.0611 (1.944) = 0.1186

ETHA = 0.0565 (16.0486) = 0.9067

THA = (0.1186 x 24.86) + (0.9067 x 10.68)
= 2.948 + 9.684 = 12.632

Personnel acquisition and training = 1.495 + 50.805
+ 12.632 = 64.932

ESTIMATED ANNUAL O$S COSTS PER AIRCRAFT

* F-4J

	Annual cost FY79$k	(FY86$k)
UNIT MISSION PERSONNEL		
1. Aircrew	140.708	(206.105)
2. Maintenance personnel	171.819	(251.676)
3. Other unit personnel	50.986	(74.683)
	363.513	(532.464)
UNIT LEVEL CONSUMPTION		
4. Petroleum, oil lubricants	268.646	(393.505)
5. Maintenance material	107.802	(157.905)
6. personnel support supplies	3.240	(4.746)
7. Training ordnance	43.400	(63.571)
	428.088	(627.052)
DEPOT LEVEL MAINTENANCE		
8. Airframe rework	75.086	(109.984)
9. Engine rework	36.252	(53.101)
10. Component rework	118.105	(172.997)
11. Other depot support	30.210	(44.251)
12. Installation of		

modifications	9.500	(13.915)
	269.153	(394.248)
SUSTAINING INVESTMENTS		
13. Replenishment spares	88.941	(130.278)
14. Replacement support equipment	-	-
15. Modification procurement	18.200	(26.659)
	107.141	(156.937)
INSTALLATION SUPPORT PERSONNEL		
16. Base operating support personnel	4.986	(7.303)
17. Health care support personnel	3.786	(5.443)
	8.702	(12.746)
INDIRECT PERSONNEL SUPPORT		
18. Base operating support	10.583	(15.502)
19. Health care support	2.660	(3.896)
20. Permanent change of station	13.986	(20.486)
21. Temporary additional duty	0.900	(1.318)
	28.129	(41.202)
DEPOT NON-MAINTENANCE		
22. General depot supply	34.694	(50.819)
23. Second destination transportation	23.595	(34.561)
24. Other support	46.144	(67.590)
	106.433	(155.900)
PERSONNEL ACQUISITION AND TRAINING		
25. Personnel acquisition	2.125	(3.113)

26. Personnel training	66.970	(98.096)
27. Transients/Holding account	17.128	(25.089)
	86.223	(126.298)
TOTAL	1397.382	(2046.346)

* F-14A

	ANNUAL COST FY79$k	(FY86$k)
UNIT MISSION PERSONNEL		
1. Aircrew	140.708	(206.105)
2. Maintenance personnel	193.069	(282.802)
3. Other unit personnel	50.933	(74.605)
	384.710	(563.512)
UNIT LEVEL CONSUMPTION		
4. Petroleum, oil lubricants	242.698	(355.497)
5. Maintenance material	127.518	(186.785)
6. Personnel support supplies	3.241	(4.747)
7. Training ordnance	50.900	(74.557)
	424.357	(621.586)
DEPOT LEVEL MAINTENANCE		
8. Airframe rework	197.520	(289.322)
9. Engine rework	80.072	(117.287)
10. Component rework	200.531	(293.732)
11. Other depot support	32.023	(46.906)
12. Installation of modifications	15.000	(21.972)

	525.146	(769.219)
SUSTAINING INVESTMENTS		
13. Replenishment spares	157.601	(230.850)
14. Replacement support equipment	0	(0)
15. Modifications procurement	148.000	(216.786)
	305.601	(447.636)
INSTALLATION SUPPORT PERSONNEL		
16. Base operating support personnel	5.365	(7.859)
17. Health care support personnel	3.989	(5.843)
	9.354	(13.702)
INDIRECT PERSONNEL SUPPORT		
18. Base operating support	11.382	(16.672)
19. Health care support	2.913	(4.267)
20. Permanent change of station	15.028	(22.013)
21. Temporary additional duty	0.300	(0.439)
	29.623	(43.391)
DEPOT NON-MAINTENANCE		
22. General depot supply	50.156	(73.467)
23. Second destination transportation	34.110	(49.943)
24. Other support	82.663	(121.082)
	166.929	(244.512)
PERSONNEL ACQUISITION AND TRAINING		
25. Personnel acquisition	2.313	(3.388)
26. Personnel training	71.674	(104.986)

27. Transients/Holding account	18.393	(26.942)
	92.380	(135.316)
TOTAL	1938.100	(2838.875)

* F-18A

	ANNUAL COST FY79$K	(FY86$K)
UNIT MISSION PERSONNEL		
1. Aircrew	39.279	(57.535)
2. Maintenance personnel	129.008	(188.967)
3. Other unit personnel	42.261	(61.903)
	210.548	(308.405)
UNIT LEVEL CONSUMPTION		
4. Petroleum, oil lubricants	162.539	(238.083)
5. Maintenance material	70.135	(102.732)
6. Personnel support supplies	3.076	(4.506)
7. Training ordnance	45.000	(65.915)
	280.750	(411.236)
DEPOT LEVEL MAINTENANCE		
8. Airframe rework	58.741	(86.042)
9. Engine rework	46.303	(67.823)
10. Component rework	75.389	(110.428)
11. Other depot support	19.257	(28.207)
12. Installation of modification	15.000	(21.972)
	214.690	(314.472)

SUSTAINING INVESTMENTS		
13. Replenishment spares	29.739	(43.561)
14. Replacement support equipment	-	-
15. Modifications procurement	25.000	(36.620)
	54. 739	(80.181)
INSTALLATION SUPPORT PERSONNEL		
16. Base operating support personnel	3.803	(5.571)
17. Health care support personnel	2.834	(4.151)
	6.637	(9.722)
INDIRECT PERSONNEL SUPPORT		
18. Base operating support	8.070	(11.821)
19. Health care support	2.065	(3.025)
20. Permanent change of station	10.257	(15.024)
21. Temporary additional duty	0.900	(1.318)
	21.292	(31.188)
DEPOT NON-MAINTENANCE		
22. General depot supply	22.162	(32.462)
23. Second destination transportation	15.072	(22.077)
24. Other suppoprt	29.689	(43.488)
PERSONNEL ACQUISITION AND TRAINING		
25. Personnel acquisition	1.495	(2.190)
26. Personnel training	50.805	(74.418)
27. Transients/Holdingaccounts	12.632	(18.503)

	64.932	(95.111)
TOTAL	920.511	(1348.339)

APPENDIX B

PRESENT VALUE COMPARISON FOR AIRCRAFT LCC

F-4J (Thousands, FY 86 dollars)

YEAR N	CASH FLOW			DISCOUNT FACTOR (10%)	PRESENT VALUE	
	ACQUISITION	O&S	INF. 6%		ACQUISITION	O&S
0	10,820			1.0000	10,820	
1		2,046	2,169	0.9091		1,972
2		"	2,299	0.8265		1,905
3		"	2,437	0.7531		1,835
4		"	2,583	0.6830		1,764
5		"	2,738	0.6209		1,700
6		"	2,902	0.5645		1,638
7		"	3,077	0.5132		1,579
8		"	3,261	0.4665		1,521
9		"	3,457	0.4241		1,466
10		"	3,664	0.3856		1,413
11		"	3,884	0.3505		1,361
12		"	4,117	0.3186		1,312
13		"	4,364	0.2897		1,264
14		"	4,626	0.2633		1,218
15		"	4,904	0.2394		1,174
16		"	5,198	0.2176		1,131
17		"	5,510	0.1979		1,090
18		"	5,841	0.1789		1,051
19		"	6,191	0.1635		1,012
20		"	6,563	0.1487		976
21		"	6,956	0.1351		940
22		"	7,373	0.1229		906
23		"	7,816	0.1117		873
24		"	8,285	0.1051		871
25		"	8,782	0.0923		811
TOTAL	10,820		118,997			32,783

F-14A

(Thousands, FY 86 dollars)

YEAR N	CASH FLOW			DISCOUNT FACTOR (10%)	PRESENT VALUE	
	ACQUISITION	O&S	INF. 6%		ACQUISITION	O&S
0	46,590			1.0000	46,590	
1		2,839	3,009	0.9091		2,735
2		"	3,190	0.8265		2,637
3		"	3,381	0.7513		2,540
4		"	3,584	0.6830		2,448
5		"	3,800	0.6209		2,359
6		"	4,028	0.5645		2,274
7		"	4,270	0.5132		2,191
8		"	4,526	0.4665		2,111
9		"	4,798	0.4241		2,035
10		"	5,085	0.3856		1,961
11		"	5,390	0.3505		1,889
12		"	5,714	0.3186		1,820
13		"	6,057	0.2897		1,755
14		"	6,420	0.2633		1,690
15		"	6,806	0.2394		1,629
16		"	7,214	0.2176		1,570
17		"	7,647	0.1979		1,513
18		"	8,106	0.1799		1,458
19		"	8,592	0.1635		1,405
20		"	9,108	0.1487		1,354
21		"	9,654	0.1351		1,304
22	-	"	10,233	0.1229		1,258
23	-	"	10,847	0.1117		1,212
24		"	11,498	0.1051		1,208
25		"	12,188	0.0923		1,125
TOTAL	46,590		165,145			45,481

F-18A

(Thousands, FY 86 dollars)

YEAR N	CASH FLOW			DISCOUNT FACTOR (10%)	PRESENT VALUE	
	ACQUISITION	O$S	INF. 6%		ACQUISITION	O&S
0	32,159			1.0000	32,159	
1		1,348	1,429	0.9091		1,299
2		"	1,515	0.8265		1,252
3		"	1,606	0.7531		1,209
4		"	1,702	0.6830		1,162
5		"	1,804	0.6209		1,120
6		"	1,912	0.5645		1,079
7		"	2,027	0.5132		1,040
8		"	2,149	0.4665		1,003
9		"	2,278	0.4241		966
10		"	2,414	0.3856		931
11		"	2,559	0.3505		897
12		"	2,713	0.3186		864
13		"	2,876	0.2897		833
14		"	3,048	0.2633		803
15		"	3,231	0.2394		774
16		"	3,425	0.2176		745
17		"	3,631	0.1979		719
18		"	3,849	0.1799		692
19		"	4,080	0.1635		667
20			4,325	0.1487		643
21			4,584	0.1351		619
22			4,859	0.1229		597
23	-		5,151	0.1117		575
24			5,460	0.1015		554
25			5,788	0.0923		534
TOTAL	32,159		78,425			21,577

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